

# SELWOOD RESEARCH, INC.

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## TEST MANUAL FOR ENGINEERING WATER TESTING OF HIGH SPEED AMPHIBIOUS VEHICLES

Contract Nonr 5016(00)  
Report Number 104-002

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OF HIGH SPEED AMPHIBIOUS VEHICLES**

**Prepared Under the Dept. of Navy  
Office of Naval Research  
Contract Nonr 5016(00)  
Report Number 104-002**

**22 April 1966**

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## FOREWORD

The United States Marine Corps is assigned responsibility for the development of equipment employed by the landing forces during the assault phase of an amphibious landing. The Landing Vehicle, Tracked (LVT), is the only major item of equipment that has been exclusively developed and used in the Fleet Marine Forces within this context. The United States Marine Corps has recently introduced other similar efforts so that it now has research and development programs in three areas:

The amphibious assault vehicle,  
The amphibious support vehicle,  
The marginal terrain vehicle, a specialized amphibious support vehicle.

The amphibious assault vehicle is unique to the United States Marine Corps. The last version to enter the Fleet Marine Forces is the amphibious assault vehicle LVTP-5 which was designed in 1950. Other versions have since been considered, the latest being the LVTPX-12, and a prototype version has just entered a Phase I and II development program.

Until recently, no amphibious support vehicle has been uniquely designed for the United States Marine Corps. The obsolescent DUKW, which was built in two months in 1941 for the U. S. Army, has been the only version used in the Fleet Marine Forces. In 1960 the United States Marine Corps decided to build several versions of a high speed amphibious support vehicle to carry a five ton payload, determined by the weight of the 105 mm howitzer, half a gun crew and one day's ammunition. Three main versions (see Figures 1, 2 and 3) were built, there being two of each type, all gas turbine powered:

LVW - Planing Hull  
LVH1- Submerged Hydrofoil  
LVH2- Surface Piercing Hydrofoil

In 1960 the United States Marine Corps decided to examine the Ground Effect Machine for the amphibious support mission and accordingly supported a substantial exploratory research program through the Office of Naval Research. This program was severely curtailed in 1962 on account of its unsuitability for the mission as presently visualized for the amphibious support vehicle. However, an air supported planing hull was regarded as having potential value. A wooden hull, designated ARCK-1 powered by two AVD 12 cylinder gasoline Continental tank engines delivering 650 SHP each, was built and tested in 1964 through 1965 (see Figure 4). In 1966 the United States Marine Corps decided to consider a vehicle version which was designated the LVK.

This test handbook is concerned with the tests of the LVW, LVH1, LVH2, ARCK, the LVK and their successors all of which can exceed a speed of 25 knots.

All United States Marine Corps research, development and test programs are approved and funded by the Assistant Chief of Staff for Research and Development, Headquarters, United States Marine Corps.



The U. S. Navy, Chief of Materiel, acts as the United States Marine Corps' Technical Agent during the selection, procurement, development and test of amphibious vehicle prototypes intended for early introduction to the Fleet Marine Forces and during their subsequent service life.

The Coordinator, Marine Corps Schools, Quantico, Virginia, examines tactics and techniques and generates General Operational Requirements and Specific Operational Requirements for the Commandant of the Marine Corps consideration and approval on all new items of materiel as well as Exploratory Research and Development Requirements. He represents the user in all phases of amphibious vehicle research, development and test. Acting in this capacity, the Chief, Amphibian Vehicle Division under the Director, Landing Forces Development Center, Marine Corps Schools, Quantico, Virginia, controls and directs test programs at the Amphibian Vehicle Division, Quantico, its West Coast Unit at Camp Pendleton, California and at other government facilities whose assistance it requests during test programs including Little Creek, Virginia (Rough Water Tests), Monterey, California (Surf Tests), Aberdeen Proving Grounds, Maryland (Automotive Tests), the Proving Grounds at Yuma, Arizona (Hot Desert Tests), Alaska (Cold Weather Tests), service and troop tests at designated locations and facilities.

The standard test procedures and handbooks are not designed to control the testing of specialized vehicles of the high speed amphibious type and the purpose of this handbook is to remedy this deficiency in certain limited respects.



**FIGURE 1: LVHX-1**

Builder: AVCO, Bridgeport  
 Loaded Weight (incl. 10,000 lb. cargo): 43,000 lbs.  
 Length/Height/Width: 36'11", 11'2", 10'10"  
 Engine: Type/HP: Lycoming TF1460 hp B1A  
 Type: Submerged Hydrofoil

**FIGURE 2: LVHX-2**

Builder: FMC Corp., San Jose  
 Loaded Weight (incl. 10,000 lb. cargo): 39,000 lbs.  
 Length/Height/Width: 37'10", 12'6", 10'6"  
 Engine: Type/HP: Solar Saturn 1040 hp gas turbine  
 Type: Surface Piercing Hydrofoil



**FIGURE 3: LVWX-2**

Builder: Chrysler Corp./Borg Warner Corp.  
 Loaded Weight (incl. 10,000 lb. cargo): 44,000 lbs.  
 Length/Height/Width: 36'8", 10'10", 11'8"  
 Engine: Type/HP: Lycoming TF20B6B1A 1500 hp gas turbine  
 Type: Planing Hull



**FIGURE 4: ARCK-1**

Builder: Bell Aerosystems, AF Hull  
 Loaded Weight (incl. 10,000 lb. cargo): 41,000 lb. (max. test weight)  
 Length/Width: 36'10 1/2", 10' 6"  
 Engine: Type/HP: Two 650 hp Continental AV-1790-2b, one Chrysler Marine 290 hp  
 Type: Air Lubricated Hull research craft



# TEST MANUAL FOR ENGINEERING WATER TESTING OF HIGH SPEED AMPHIBIOUS VEHICLES

## 1.0 INTRODUCTION

### 1.1 Purpose

The purpose is to provide simple and standard methods for issuing test directives to test units. Standard tests required on vehicles will be identified by numbers from this manual; special instructions will be added as necessary.

### 1.2 Scope

The manual is presently restricted to water tests on high speed amphibious support vehicles and to the engineering phase of those water tests.

### 1.3 Other Types of Testing

Land Tests at the Aberdeen Proving Grounds, hot weather tests at Yuma, cold weather tests, endurance tests both water and land, tropical tests, service and troop tests are not included here.

### 1.4 Background

The high speed amphibious support vehicle is used in the support phase of an amphibious assault. It must be capable of high water speeds, have good capabilities in surf, beach crossing and cross country mobility. Continuous operation is required in sea states up to and including sea state 3 and in plunging surf up to ten feet. It will be used primarily as a tactical/logistical support vehicle to transport towed artillery, supplies, equipment and personnel from ships up to 25 miles offshore to points up to 30 miles inland.

### 1.5 Definition of Engineering Test

This is a test conducted by or under supervision of a separate test agency, not a part of developing installation or technical agent concerned, using an engineering approach, where the objective of the test is to determine the technical performance and safety characteristics of an item or system and its associated tools and test equipment as prescribed in the SOR, the technical characteristics and as indicated by the particular design. This determination includes the measurement of the inherent power, motion, structural, electrical, or other physical and chemical properties and may utilize data previously generated in Engineer Design Test. The test is characterized by controlled conditions and the elimination of human errors in judgment, so far as possible, through the utilization of environmental

chambers, physical measurement techniques; controlled laboratory, shop, and field trials; statistical methodology; and the use of personnel trained in the engineering or scientific fields. The engineering test provides data for use in further development and for determination as to the technical and maintenance suitability of the item or system for service test. Reference 8.1.

## 1.6 Other Definitions

1.6.1 Appendix D contains a partial list of definitions applicable to official terminology and tests used in this document.

1.6.2 The following tests are defined in Appendix D:

- Check Test
- Confirmatory Test
- Comparison Test
- Integrated Engineering Service Test
- Military Potential Test
- Product Improvement Test
- Service Test
- Troop Test

## 1.7 Evaluation

An evaluation is an appraisal of an idea, report, study, research, development or test to determine the suitability of the idea, report etc., for military use, or by appraisal to determine whether further study, research, development or testing is necessary or warranted to determine such suitability. An evaluation will be conducted when the extra effort involved in a detailed test or service test would be of little or no greater value than an appraisal in determining suitability. Limited testing or testing of components may be required to give sufficient information to complete an appraisal.

## 1.8 Administrative Instructions

### Test Directive

The initial test directive issued by the Chief, Amphibian Vehicle Division, Landing Forces Development Center, Marine Corps Schools, Quantico, Virginia will lay down general guidelines for:

- \* The specific tests required
- \* The order in which groups of tests should be done
- \* The priority
- \* The completion dates

1.8.1 The test units on receiving the directive will schedule and plan the actual test runs. It is realized that both completion dates and the most expeditious methods are often determined by extraneous factors such as weather, availability of instrumentation and test personnel, vehicle serviceability, etc. Frequently, several tests, even with different priorities, can be conducted simultaneously with no loss in time.

1.8.2 No major modifications will be made to the test items unless authorized by the Amphibian Vehicle Division.

1.8.3 Reports

(a) The test schedule, drawn up before tests are commenced, will be updated monthly.

(b) Tests will be itemized in detail and data sheets will be prepared and forwarded to the Chief, Amphibian Vehicle Division, Marine Corps Landing Forces Development Center.

(c) Progress reports will be submitted in triplicate monthly during the conduct of the tests. These reports will be written in narrative form and will consist of the following for the reporting period:

A summary of vehicle operation

Performance data collected

Records and descriptions of defects

(d) Any unusual failures or deficiencies will be reported to the Project Officer, Amphibian Vehicle Division, Marine Corps Landing Forces Development Center by telephone.

(e) A separate final report will be written in triplicate unless otherwise specified.

1.9 Evaluation or Interpretation of Test Results

The test units' functions do not include formal interpretation of results. Such interpretations will depend upon the establishment of standards and experience as well as the state of evolution of the vehicle being tested and the purpose of the tests. The test units may forward informal interpretations or evaluations by separate letters accompanying reports.

## 2.0 INITIAL INSPECTIONS AND TESTS, STANDARDS, DEFINITIONS

### General

The tests, inspection and installations outlined below will be conducted from engineering and safety view points.

Preliminary tests will be considered complete when:

- \* The operator has demonstrated sufficient confidence in and familiarity with the test item to proceed with the engineer tests.
- \* Adequate instrumentation schedules, special tools, spare parts and manuals are on hand.
- \* Chronic mechanical deficiencies have been eliminated.

### Test No. 2.1 - Pre-Operational Inspection and Physical Characteristics

#### Purpose

- \* To conduct pre-operational inspections and measure physical characteristics.
- \* To insure that the test item is in proper condition for engineering tests.
- \* To install or check out additional instrumentation required for the engineering test.
- \* To familiarize operation and maintenance crew with the test item.

#### Method

2.1.1 Inspection. Test item will be subjected to a technical inspection upon receipt as prescribed by technical manuals and other appropriate publications. Basic alignment data will be obtained and datum references will be provided so that frame twisting and steering alignment can be checked in subsequent phases of the testing. Test item will be photographed from sufficient angles to depict its important aspects. Dimensioned outlined elevation and plan drawings will be prepared.

2.1.2 Weighing. Test item will be weighed, measured, photographed and checked for other pertinent characteristics. Weight and balance diagrams will be prepared or checked including all items of fixed and removable equipment.

2.1.3 Instrumenting. Preliminary estimates will be made of the data to be recorded; adequate instrumentation will be procured, installed and checked out from the operating, calibration, installation and environment aspects.

2.1.4 Break In. The test item will be operated on water and land sufficiently to insure operator familiarization, freedom from chronic mechanical failures and hazards, and satisfactory functioning of the basic instrumentation. A record will be made of servicing performed, equipment faults discovered and corrections made.

#### Test No. 2.2 - Initial Stowage Inspection

##### Purpose

- \* To assure that all on-equipment-material (OEM) has been provided and that the material can be adapted to the test item for use from a stowed condition.

##### Method

- 2.2.1 Install all equipment making certain that it is properly installed so that this equipment will not interfere with the normal operation of the test item and does not occupy cargo space.

#### Test No. 2.3 - Initial Lubrication and Servicing

##### Purpose.

- \* Establish fuel, lubricant, and hydraulic fluid requirements. Determine refueling rate (50 gpm essential), accessibility of fittings and drain plugs, tools required and time involved in performing complete service. This will provide familiarization with lube requirements for operations.

##### Method

- 2.3.1 Drain all fluid systems and grease all lube points. Refill with recommended military grade fuels, lubes and fluids. Inaccessibility, special tools required, extremely long drain periods, capacities and other pertinent data will be recorded.

## Test No. 2.4 - Log Books

### Purpose

- \* Maintain a daily record of the number, type and duration of runs; a record of fuel, oil and lubrication; a record of inspections, defects and modifications, and a statement on the serviceability conditions.

### Method

- 2.4.1 Standard log books will be used and will be entered daily whenever any engine is run or work is done on the test item.

## Test No. 2.5 - Maintenance and Servicing

### Purpose

- \* To check the adequacy of special tools, spares, repair kits, maintenance and servicing instructions, manuals and procedures.

### Method

- 2.5.1 Records will be kept of oil, fuel and lube consumption, inspections, defects, repairs, servicing and maintenance. The adequacy of procedures, kits, spares, instructions and manuals will be checked during the engineering tests to insure adequacy for service tests. See item 5.5 also.

## 2.6 Definitions and Standards

### Purpose

- \* To establish standard definitions of weight, center of gravity and speed for testing purposes.

### Method

- 2.6.1 All competitive vehicles should be tested under the same conditions, or at best, as near to the same conditions as practicable; hence, the choice of standard values to represent such conditions.
- 2.6.2 The reason for testing at a standard weight, center of gravity and speed is that they cannot all be varied for all conditions of sea state, heading etc. The amount of testing would then exceed weather availability and vehicle serviceability and would be unduly costly. This subject is discussed further in the appropriate test sections, particularly in Test No. 4.0 and Appendix C.



The following weighing and preliminary, or calm water speed trials, standards will be adopted as follows:

### 2.6.3 Weight

Light Weight	This will be the weight of the vehicle in fully operational condition for testing, including crew, fuel, instrumentation, but not test payload.
Maximum Weight	This will be the same as the "light weight" plus payload. (Normally 10,000 pounds including instrumentation and instrumentation personnel or sufficient payload to bring the weight to a maximum safe or practical operating weight.)
Medium Weight	This will be the same as the "light weight" plus half the difference between light and maximum weight.
Standard Test Weight	This will be a single weight as specified by the Chief, Amphibian Vehicle Division and will usually be either the medium or the maximum weight.

### 2.6.4 Center of Gravity or Trim

Aft Center of Gravity	This will be the center of gravity at maximum weight with the load distributed as far aft as the test item will tolerate for reasonable acceleration to maximum speed in rough water.
Forward Center of Gravity	This will be the center of gravity at maximum weight with the load distribution as far forward as the test item will tolerate for reasonable acceleration to maximum speed in rough water.
Mid Center of Gravity	This will be the average between the fore and aft positions.

Standard Center of Gravity

This will be a single center of gravity as specified by the Chief, Amphibian Vehicle Division and will usually be the mid center of gravity.

#### 2.6.5 Test Speed

Maximum Speed

This will be the maximum speed attained in calm water trials at light load.

Standard High Speed

This will be a single speed as specified by the Chief, Amphibian Vehicle Division and will usually be in the vicinity of 25 knots.

Hump Speed(s)

This will correspond to the speed at standard weight and standard center of gravity at which the vehicle is barely able to take off a plane. It will vary with load and trim.

Standard Low Speed

This will be a displacement speed below which the lift contribution from planing is minor and will usually be in the vicinity of 5 to 8 knots as specified by the Chief, Amphibian Vehicle Division.

#### 2.6.6 Sea State

From the Wilber Marks table, Reference 8.2, a fully arisen sea state 3 is shown to occur in wind velocities of 14 knots to 16 knots. The average wave heights are 2.0 to 2.9 feet and the average of the one third highest waves 3.3 to 4.6 feet (significant wave height). A wide range of periods, from 1.5 seconds to 8.8 seconds, is indicated and this is influenced by the fetch and depth of the location. Generally short steep seas occur in shallow waters and where a short fetch has produced the sea. Corresponding ranges for sea state 2 are: average height 0.88 to 1.8 feet, significant 1.4 to 2.9 feet, and period 1.0 to 7.6 seconds.

The shorter steeper seas, with small period, are closer to the natural pitch frequency of the vehicles in the 20 ton class, and produce more severe motion.

## 2.7 Priorities

### Purpose

- \* To insure that tests are conducted in an order consistent with weather, test item serviceability and order of importance of the tests.

### Method

2.7.1 The order of priority will be stated by the Chief, Amphibian Vehicle Division. The normal order is as follows:

Priority A Initial Inspections, etc. Test No. 2.0

Priority B Calm Water Tests Test No. 3.0

Priority C Rough Water Tests Test No. 4.0

4.1.0 Power

4.2.1 Broaching and Roll

4.2.2 Heading

4.2.3 Center of Gravity, Height

4.2.4 Center of Gravity, Fore and Aft

4.2.5 Center of Gravity, Beamwise

4.2.6 Moments of Inertia (Note: This test will usually be deferred to a lower priority.)

Priority D Land Tests

Priority E Mechanical, Structural and Hull Design Tests

Priority F Special Tests

### 3.0 CALM WATER TESTS

#### Test No. 3.1 - Righting Moment

##### Purpose

- \* To conduct inclining tests thus determining the transverse stability (righting moment) of the test item versus heel angle.

##### Method

- 3.1.1 Determine the relation between the center of gravity height at different loads up to 10,000 pounds plus 25% overload, angle of roll, period of roll and righting moment. Test item will be moored alongside a control vessel at dock-side with disturbing moment applied by ropes attached to the control vessel. Bilge pumps will be checked before testing is commenced and bilge water levels will be checked during tests.

#### Test No. 3.2 - Towing

##### Purpose

- \* To tow the test item in water and onto the beach, thus to insure adequate provisions for recovery in the event of a power or transmission failure.

##### Method

- 3.2.1 A towing bridle will be attached to the bow towing eyes. The test item will be towed at water speeds up to 8 knots or the safe maximum speed, whichever is lower. The test item, with the wheels down, will be winched or towed ashore on a shallow sand shelf.

#### Test No. 3.3 - Speed Calibration

##### Purpose

- \* To relate the speed readings obtained from instruments permanently mounted on test items with the speeds recorded separately and with great reliability by running test items at constant speed(s) over a time--distance course.
- \* To insure a means for measuring speed under transient speed conditions in different sea states and different headings.

##### Method

##### 3.3.1 Transits

Markers will be set in pairs one statute mile (approximately)

coinciding at each end of the course will be measured by a stop watch.

### 3.3.2 Camera

Markers are similarly set up as described in 3.3.1 but about 200 feet apart. Mirrors are set behind the rear markers. A camera driven by a synchronous motor is placed between marker sets and is traversed to record the passage between sets. Elapsed time is a function of the number of frames and interpolation on the distance between the test item and markers on the last frame. The times for three pairs of reciprocal runs are averaged.

### 3.3.3 Buoys

Buoys are set about one mile apart. The distance between the buoys will be measured either by a length of floating wire or by three independent surveys from land. Time to travel between buoys will be measured by stop watch.

### 3.3.4 Miscellaneous

The transverse component of current should be allowed for when significant. For example, a transverse component of 14% of the measured speed will give an error of 1% low. A component of 20% will give 2% low.

## Test No. 3.4 - Component Cooling in Water Operation

### Purpose

- \* To determine stabilization of temperatures (heat balance) in critical areas and components.

### Method

- 3.4.1 A water endurance run will be conducted in loaded condition in rough and calm water at maximum safe operating speeds for the prevailing sea condition. Sea conditions and test item speed will be noted when temperatures are recorded.

## 3.5 Speed (Constant)

### Purpose

- \* To assist in determining propeller cruising efficiency.

- \* To provide certain fixed speeds for stability, maneuvering and environmental tests.
- \* In conjunction with rpm and fuel consumption, to provide data for navigational purposes.

### Method

The test item will be run at a number of fixed shaft or test item speeds under the following conditions:

- 3.5.1 Runs will be made at about five speeds at and below the hump speed and at about five speeds including maximum speed above the hump speed.
- 3.5.2 The following measurements are required; water speed, propeller pitch (before and after tests to check on distortion), propeller shaft rpm, torque and thrust, trim angle during a run.
  - a) When using a speed instrument, the duration at each speed should be sufficient to steady out the test item.
  - b) When running a fixed distance course, sufficient time to steady out should be allowed before entering the course. Also, in this instance, runs at reciprocal headings will be required at each speed to cancel out current effects.
  - c) Three considerations will result:
    - Data for insuring a high (relatively speaking) propeller efficiency at low speed in order to minimize installed horsepower;
    - A standard speed for low speed tests;
    - A standard speed for other tests above hump speed.

## 3.6 Acceleration

### Purpose

- \* To determine the time and power required to attain operating speed at different engine throttle settings.

### Method

The test item will be accelerated from rest to maximum speed at four different throttle settings or methods of throttle operation as follows:

- 3.6.1 Setting(s) to give minimum time to maximum speed.
- 3.6.2 A repeat of 3.6.1.
- 3.6.3 A lesser throttle setting(s) in accordance with operator's judgment of an acceptably smooth operation involving less than maximum rpm or boost.
- 3.6.4 A throttle setting(s) corresponding to the minimum power necessary to achieve acceleration over the hump.
- 3.6.5 The same parameters are measured as in Test No. 3.5 plus time.

### Test No. 3.7 - Fuel and Oil Consumption

#### Purpose

- \* To determine the cruising range of the test item with and without payload.

#### Method

##### 3.7.1 Fuel

Cruising range will be determined by installing a flow meter and continuously recording flow rates during constant speed and load trials simultaneously with water speed, rpm and torque as per Test No. 3.5

##### 3.7.2 Oil

Oil consumption will be measured throughout the tests by dipping the tank before and after each test. Oil additions will be entered in the log book by time and date.

### 3.8 Shaft Horsepower

#### Purpose

- \* To determine power input to the propeller.
- \* To determine power output from the engine drive shaft.

Note: Unless specifically requested, the second item is usually not measured.

Method

- 3.8.1 A torque meter is inserted into the propeller shaft as close to the propeller as possible.
- 3.8.2 RPM is measured at some convenient location in the drive system, having a fixed gear ratio with the propeller shaft.
- 3.8.3 Torque and rpm are recorded during the speed trials described in Test Nos. 3.5 and 3.6.

3.9 ResistancePurpose

- \* To measure hull resistance at varying speeds.
- \* To provide a base for determining the value of changes to hull or rudder shape, appendage changes etc.
- \* To provide one of the bases for measuring propeller efficiency.
- \* To provide a base for measuring resistance changes in rough water.
- \* To provide a base for measuring the effects of changes in trim or weight on hull resistance.

Method

- 3.9.1 A thrust transducer is provided for sensing or directly measuring the propeller thrust on its shaft.
- 3.9.2 Thrust, torque and rpm are recorded during the speed trials described in Test Nos. 3.5 and 3.6.

3.10 Engine Brake HorsepowerPurpose

- \* To measure engine power output as a function of various engine parameters such as barometric pressure, air temperature, spray intake, fuel, exhaust temperature, rpm, accessory load.
- \* To measure shaft wind up in starting or reversing.
- \* To determine total losses including gears and transmission between the engine and propeller.

Note: This parameter is not normally required to be measured.



Method

3.10.1 A torque meter and rpm indicator are located on the engine output shaft.

3.10.2 Measurements are made during Test Nos. 3.5, 3.6, and 4.2.

3.11 Propeller EfficiencyPurpose

- \* To measure the efficiency of a given propeller as a function of speed, displacement, trim and sea state.
- \* To conduct similar tests on a series of propellers which, in conjunction with analytical determinations, can be used to select or design the propeller type best suited to the required task.

Method

3.11.1 Data are obtained by conducting Test Nos. 3.5 through 3.9 and 4.1 as appropriate.

3.11.2 Propellers are changed and polished as required.

3.11.3 Blade settings on variable pitch propellers are measured as required.

3.11.4 Propeller angle of advance will be measured before and after tests to check on permanent set.

3.12 Bollard PullPurpose

- \* To check towing ability.
- \* To provide a dynamic calibration of the thrust transducer (part load).
- \* To provide a static calibration of the thrust transducer up to full load.

Method

3.12.1 The test item is secured to a suitable bollard by means of a cable containing a tension meter. The cable and bollard should be close to water level to reduce changes in the pitch angle as the load increases. Tests must be conducted in absence of currents. Remote read out should be provided to avoid the hazards of whip-lash due to cable parting. RPM will be steadied at equal increments

Readings from the test item's thrust transducer and the calibrated transducer in the cable will be recorded simultaneously. Corrections will be made for cable and shaft angles.

- 3.12.2 The test item is secured on land. The propeller is replaced with a suitable adapter containing a calibrated transducer to which incremental loads can be applied. Simultaneous recordings are made of the test item's permanent thrust meter and the calibrated transducer.

### 3.13 Weight and Center of Gravity Determination

#### Purpose

- \* To determine the test item's weight and fore and aft center of gravity at a known standard condition.
- \* To determine the vertical center of gravity at the same condition.
- \* To determine the military loading requirements. See also Test No. 5.7.

#### Method

- 3.13.1 The test item's condition will be pre-determined, i.e. the location and weight of residual fuel, oil, fixed and removable items of equipment will be logged as stated in Test No. 2.1.2.
- 3.13.2 Using the standard Navy sling, the test item will be hoisted by a single attachment to the crane, trimmed level, and at two or more angles fore and aft. The angle of the hoist relative to the test item will be recorded or photographed, thus providing horizontal and vertical center of gravity positions. Or, the test item will be supported by dynamometers at different levels fore and aft to yield the same information.
- 3.13.3 Tests will be done with retractable wheels, sponsons, foils, propellers in both fully up and down positions.
- 3.13.4 Calculations will be made, based upon Test No. 5.7 and other relevant data of the amount by which the loads' center of gravity can move fore and aft, sideways or vertically. The loading diagram will be marked accordingly.

### 3.14 Trim (Center of Gravity)

#### Purpose

- \* To determine by tests reasonable extremes of trim at which the craft will perform satisfactorily or is safe to operate.

### Method

- 3.14.1 The extremes of load movement beyond which the craft is unsafe to operate or fails to take off and plane will be determined firstly by calm water tests and secondly by rough water tests. This will be accomplished with lead ballast corresponding to half and full loads at the fore, mid and aft positions, and zero load as determined by Test No. 3.13, i.e. a maximum of seven positions.

### 3.15 Heel

#### Purpose

- \* To determine the effect of misloading or accidental beamwise cargo shift on the ability of the test item to take off or maintain a constant heading.

#### Method

- 3.15.1 The test item will be ballasted to full load at the mid center of gravity (Item 2.6.4 ) and the load displaced 5% and 10% of the beam width in successive stages to port (or starboard). The test item is accelerated to maximum speed and to three or four other constant speeds and the change in heel angle is noted.

## 4.0 ROUGH WATER TESTS

### 4.1 Power

#### Purpose

- \* To determine the additional power and fuel consumption required for take off and cruising as the sea increases in height and varies in wave length in the region between sea states 2 and 3, or conversely the reduction in payload or speed for satisfactory operation.

#### Method

The following will be varied or recorded as in the calm water power tests 3.0.

- 4.1.1 Temperature Stabilization
- 4.1.2 Speed (Constant)
- 4.1.3 Acceleration
- 4.1.4 Fuel Consumption
- 4.1.5 Shaft Horsepower
- 4.1.6 Resistance
- 4.1.7 Brake Horsepower
- 4.1.8 Propeller Efficiency
- 4.1.9 Weight and Center of Gravity
- 4.1.10 Sea States 2 and 3
- 4.1.11 Power tests are conducted into a head sea or a following sea depending upon whether the vehicle is the planing hull or hydrofoil type respectively.

### 4.2 Stability

#### Purpose

- \* To measure roll angle when lying broached to a heavy sea, such as occurs with engine failure. See also Test No. 3.15.
- \* To record roll angle during low and high speed runs simultaneously with pitch angle and rate of turn to observe any tendency to high speed broaching or to provide data should it occur.
- \* To record roll and pitch angles and frequency as possible indicators, in conjunction with other factors, of motions conducive to motion sickness.
- \* To record vertical acceleration and frequency to determine the effect of slamming on the ride comfort.

- \* To record the effect of the vertical center of gravity position and of the moment of inertia on the above factors.

### Method

#### 4.2.1 Broaching and Roll

The craft in turn lies to at rest and proceeds at the standard low and high speeds in each of the beam seas of interest, i.e. extremes of height and wave length in the sea state 2 and 3 region, for about 200 wave crests. The roll angle will be recorded on a time base simultaneously with pitch angle, rate of turn, vertical acceleration at the driver's seat, the standard center of gravity location and at the stern. At the test unit's option, spot checks can be made on horizontal lateral and surge accelerations at the normal center of gravity location.

The tests will be conducted at the standard weight.

#### 4.2.2 Heading

Similar data are recorded as in Test No. 4.2.1 at the two standard speeds and the standard weight and center of gravity with the vehicle headed into the sea, four points on the port bow, beam sea, four points on the quarter and astern. Tests will be done in sea states 2 and 3.

#### 4.2.3 Center of Gravity - Height

Test Nos. 4.2.1 and 4.2.2 will be repeated as necessary to insure coverage of the vertical center of gravity positions at low, medium and high positions. The fore and aft center of gravity will be located at the mid positions. Tests will be done in sea states 2 and 3.

#### 4.2.4 Center of Gravity - Fore and Aft

Test Nos. 4.2.1 and 4.2.2. will be repeated as necessary to insure coverage of the center of gravity at the fore and aft positions. Weight will be standard and center of gravity will be at the highest position. Tests will be done in sea states 2 and 3.

#### 4.2.5 Center of Gravity Offset Beamwise

Test Nos. 4.2.1 and 4.2.2 will be repeated as necessary with the maximum load moved five and ten per cent, of the beam width, to port. Weight will be standard and the center of gravity will be at maximum height. Tests will be done in sea states 2 and 3.

#### 4.2.6 Variation in Moments of Inertia

Tests will not normally be done on this parameter unless stability or ride quality difficulties are experienced in the preceding tests which may appear to be sensitive to moment of inertia changes. In the latter instance, the ballast can be repositioned fore and aft, beamwise, or vertically as appropriate to change the moment of inertia. Tests 4.2.1 and 4.2.2 would then be repeated as necessary. Tests will be done in sea states 2 and 3.

### 4.3 Control

#### Purpose

- \* To determine maximum rates of turn.
- \* To determine maneuverability on one engine or propeller.
- \* To determine the time and distance to reverse direction of motion.

#### Method

- 4.3.1 Rates of turn will be measured with a rate gyro at rudder angles of nominally 10, 20 and 30 degrees at very low speeds, say 2 and 4 mph, at 8 and 10 mph, at 25 mph and maximum speed. Engine rpm (thrust) will be equalized initially. Tests will be repeated with unequal engine thrust. Tests will be done in calm water and sea states 2 and 3. Using a stop watch, the time taken to turn through 180° will be measured in each test.
- 4.3.2 The ability to maintain a seaway or maneuver with power from one engine only will be checked.
- 4.3.3 With the weight and center of gravity at standard values, the vehicle will be put into reverse as quickly as the safe operation of gear boxes, clutches and engine limitations will permit, from steady forward speeds corresponding to maximum and standard speeds. Speed will be recorded during the operation. The time between giving the order for crash reverse and the vehicle reaching a standstill will be recorded with a stop watch. The distance covered will be found from the area under the speed time recording, using the stop watch time.

$$S = \int_{T_2}^{T_1} V, dt$$

where S = distance covered

$T_2$  = time recorded on the tape at which test item came to rest

$T_2 - T_1$  = elapsed time measured by the stop watch

V = velocity recorded on the tape between times  $T_1$  and  $T_2$

#### 4.4 Environment

##### Purpose

- \* To determine the amount of spray formed and its effect on the craft's suitability as a cargo or troop carrier.
- \* To determine the effect of motion on the craft's compatibility as a cargo or troop carrier.
- \* To measure noise level, air temperature and vibration at suitable locations.

##### Method

- 4.4.1 Spray collectors will be located at suitable positions and the quantity of water collected over a measured time will be observed during typical operations. Movie camera records will also be taken both on board and from an observation craft for comparison with other craft.
- 4.4.2 Noise levels will be measured by a decibel meter at various parts of the test item.
- 4.4.3 Noise and vibration will be recorded on tape for subsequent analysis, if requested.

#### Test No. 4.5 - Surf

##### Purpose

- \* To determine the test item's ability to negotiate different types of surf, up to a possible maximum of ten feet plunging surf, when approaching and leaving the beach and also its maximum safe surfing capability.

##### Method

- 4.5.1 The test item will be loaded in suitable increments with variations of center of gravity position at the discretion of the test Project Officer and tests conducted in surf in suitable increments in height commencing with breaking surf and ending with plunging surf. The presence of wind and lateral currents will be noted and measured. Surf height and wave length will be recorded. The test item's ability to enter and leave the water and its controllability in surf will be noted. Roll, pitch, rudder angles, engine characteristics, rate of turn, and carbon monoxide concentration will be recorded.
- 4.5.2 Detailed surf testing procedures are described in Appendix C.
- 4.5.3 The maximum surf height to be attempted will vary with the type of vehicle and therefore will be specified by the Chief, Amphibian Vehicle Division individually for each test item.

## 5.0 FUNCTIONAL SUITABILITY

### Test No. 5.1 - Human Factors

#### Purpose

- \* To ensure crew, passenger and test item safety and efficient operation.
- \* To determine whether the test item is suitable with respect to other human engineering aspects, including compatibility with the skills, aptitudes and limitations of the operating and servicing personnel.

#### Method

- 5.1.1 All controls and control arrangements will be reviewed and deficiencies noted from the viewpoint of accidental operation, vehicle safety, undue or unnecessary stress on the operator.
- 5.1.2 All safety equipment, exits, hand and foot holds, loading ties, etc. will be reviewed for safe and efficient operation. Outward opening or sliding exits are not acceptable.
- 5.1.3 Night tests will be conducted to check the suitability of test item internal and external illumination, field of vision, etc.
- 5.1.4 Brief tests will be run and comments made on requirements for navigation in dense harbor traffic, waterways, off a landing beach and in long range ship-to-shore movement.
- 5.1.5 Noise developed by the engine or due to water impact, panel vibration, accessories, etc. will be noted and comments made on the noise levels and adequacy of different methods of communication on the test item. Radio interference will be checked.
- 5.1.6 Tests for toxic fumes in crew and cargo compartments will be made.
- 5.1.7 To the maximum extent practical, personnel and equipment will be loaded into the test item. The test item will then be operated cross-country at least 50 miles and the personnel dismounted. Data with respect to the following will be recorded.
  - a) Ease and speed of personnel mounting and dismounting with equipment.
  - b) Adequacy of seats.
  - c) Adequacy of padding and lack of injurious projections for safety in cross-country ride.
  - d) Number of personnel.



- e) Physical condition of personnel after test.
- f) Comments of personnel on endurance tolerable in different locations on deck.
- g) Exposure to wind, dust and heat.

5.1.8 The procedure in 5.1.7 will be repeated with the test item operated 25 miles at high cruising speed in a sea state 2 and comments will be made on the same items as appropriate.

5.1.9 See Appendix A for detailed procedures involved in human engineering testing and analysis.

## 5.2 Compatibility With Shipping

### Purpose

- \* To determine the capability of the test item to embark on or debark from the LSD, LPD, and LST.

### Method

- 5.2.1 The test item will be engaged in boarding and debarking operations from LST and LPD, and if available an LSD.
- 5.2.2 Ability of the test item to enter and withdraw from mezzanine decks will be checked.
- 5.2.3 Refuelling will be conducted.
- 5.2.4 Test item will be loaded from side booms and its ability to hold station and avoid entrapment by ship rolling and heaving will be checked.

## Test No. 5.3 - Adequacy of OEM and OERP and Stowage Facilities

### Purpose

- \* To determine adequacy of the OEM.
- \* To determine the requirement for OERP.
- \* To determine the adequacy of stowage provisions for the OEM and OERP.

Method

- 5.3.1 Throughout the conduct of the test adequacy and importance of OEM and OERP will be evaluated. Recommendations as to additions or deletions will be made.

Test No. 5.4 - Compatibility With Related EquipmentPurpose

- \* To determine the compatibility of the test item with related vehicles and equipment.

Method

- 5.4.1 The test item will be used to tow similar and lighter vehicles, and will be recovered from immobilized beach positions and be towed by recovery vehicles or transporters. Any incompatibility or failure of towing devices will be reported. See also Test No. 3.2.
- 5.4.2 The radio set will be used as required during operations of test item and separately on as many occasions as required to obtain valid results. Compatibility of the radio set with the test carrier will be evaluated to include ease of installation and operation and any interference with operation of the test item.
- 5.4.3 The test carrier will be operated in the vicinity of standard type radios during simulated tactical conditions. Any adverse effect on radio reception or transmission will be reported.
- 5.4.4 Adequacy of lifting and tie-down devices for rail, air and amphibious transport will be evaluated.
- 5.4.5 Throughout all winter operations the heater for the test carrier will be utilized as required. The adequacy of the heater will be evaluated.

Test No. 5.5 - MaintenancePurpose

- \* To determine whether maintenance of the test item can be accomplished readily.
- \* To accumulate parts usage data.

- \* To accumulate data pertaining to man hours expended in maintenance.
- \* To review the maintenance manuals included in the maintenance package for the purpose of recommending necessary changes, deletions, additions, and corrections.

#### Method

- 5.5.1 Using appropriate tools, all necessary authorized maintenance will be performed on the test item. First echelon maintenance will be performed in an unsheltered area during the winter by crews attired in complete arctic winter clothing to include appropriate arctic hardware. Second echelon maintenance will be performed outdoors under field conditions during the winter to an extent sufficient to determine whether it can be accomplished under these conditions. Data will be recorded with respect to the following:
- a) Man hours required to perform first echelon maintenance.
  - b) Man hours required to perform second echelon maintenance.
  - c) Total man hours expended in maintaining the test item broken down as to scheduled (first and second echelon) and unscheduled maintenance.
  - d) Difficult and time consuming operations.
  - e) Adequacy of organizational tools for performance of second echelon maintenance.
  - f) Adequacy of maintenance instructions.

#### Test No. 5.6 - Modification

##### Purpose

- \* To determine modifications necessary to make the test item suitable for Marine Corps use in amphibious operations.

##### Method

- 5.6.1 Approved modifications made on those items of test item components determined to require modification will be accomplished, recorded and reported during the test and at the completion of testing.

## Test No. 5.7 - Load Functional Suitability

### Purpose

To determine the suitability of the test item as a:

- \* Cargo Carrier
- \* Personnel Carrier
- \* Prime Mover

### Method

5.7.1 The test item will be loaded to capacity with respective loads of class I, III and V supplies; the total load in each case will not exceed the rated payload of the carrier. The test item will be driven cross-country a distance of at least 10 miles with each type load and then unloaded. Data with respect to the following will be recorded:

- a) Ease of loading and unloading cargo.
- b) Adequacy of doors or ramps for loading and unloading cargo.
- c) Types of load carried.
- d) Adequacy of cargo space.
- e) Suitability of cargo tie-downs.
- f) Any adverse effect on cargo and on test item.

5.7.2 The tests in 5.7.1 will be repeated as appropriate with the test item operated at high cruising speed for a distance of 10 miles in sea state 2.

5.7.3 To determine drawbar pull data, the vehicle will be tested with a load cell in a tow cable attached either to a second heavier vehicle or anchored to the ground. Maximum pull will be recorded for:

- a) Vehicle at light weight and maximum.
- b) Towing from the front and rear.
- c) Mud, sand, shingle, earth, macadam and concrete.
- d) Wet conditions and dry.
- e) Towing up slopes of varying grades.

## 6.0 MECHANICAL, STRUCTURAL AND HULL DESIGN

### Purpose

- \* To determine hull etc. efficiency by measuring the water pressure at various positions in calm water.
- \* To determine dynamic loading for structural design purposes by measuring impact pressures at various positions in rough water.
- \* To determine load and stress distribution between key members of the structure by measuring their strain in rough water.
- \* To determine the presence of loading conditions conducive to rapid fatigue failure in key members such as shafts, struts, foils, flaps, etc.

### Method

#### 6.1 Pressure, Calm Water

Pressure taps are located on the undersurface and the static pressure is recorded simultaneously with speed at standard and maximum loads. Speed should be varied incrementally as in Test No. 3.5 and the craft should also be accelerated as described in Test No. 3.6.

#### 6.2 Pressure, Rough Water

The same pressure taps should be used to record on a time base the variation in pressure (static) as the craft heaves and slams in rough water. The conditions of test will be the same as for Test No. 4.2 except that recordings can be limited to previously established worst slamming conditions, if known.

#### 6.3 Strain

The arrangement of the tests will be identical with the rough water pressure tests, and both may be done simultaneously. These tests probably will not be done concurrently with the other tests mentioned in this program because of instrumentation overcomplexity, low reliability due to the salt water environment and lower priority.

The structural members to be gauged, the position of the gauges, the design stresses and materials specifications will be submitted by the craft's builder. This will be reviewed by the Chief, Amphibian Vehicle Division and a test plan forwarded to the test unit.

#### 6.4 Vibration or Flutter

Vibration or flutter tests will usually be required only if fatigue failures occur during tests or service. The suspected member will be fitted with suitably calibrated accelerometer or strain gage transducers, as appropriate. The test item will be accelerated slowly in calm water and the records will be examined for resonances at various speeds or shaft speeds. The test item will then be run for substantial times at the resonant conditions to confirm the preliminary indications. The malfunctioning part will then be replaced with a modified part and the tests repeated until the trouble is eliminated. Proof tests may also be required in rough water.

## 7.0 SPECIAL TESTS

### 7.1 Cushion Tests

#### Purpose

- \* To determine the air horsepower delivered in the duct(s) with a stationary hull seal and no leakage.
- \* To determine approximately the air horsepower delivered in the ducts with the vehicle moving at different speeds and weights in calm and rough water.
- \* To determine the effect of air horsepower on motion and cushion washout in rough water.

#### Method

##### 7.1.1 Stationary Calibration Tests

Moving ventilators such as flaps will be fixed in the closed position. The underside of the hull will be sealed with a plate joining the lower edges of the keels and the rear will be left open. A battery, say 24, of pitot static tubes will be spread at a suitable position near the exit of the main duct(s) in the hull and connected to a water manometer. The fan or compressor will be run at a series of steady incremental measured speeds and the manometer pressures will be correspondingly recorded.

##### 7.1.2 Moving Water Tests

- a) Pressure transducers capable of detecting dynamic pressure to  $\pm 1/2$  psi and static pressure will be connected to a pitot static head located in the duct at a location selected from a review of the tests, 7.1.1.
- b) Calm water power tests, i.e., Test Nos. 3.5 through 3.11, will be run at the mid center of gravity position with light, medium and heavy loads each with three known levels of air delivery as approximated by fan rpm.
- c) Rough water tests, i.e. Test Nos. 4.1, 4.2 and 4.3, will be run at the standard center of gravity and weight with the same three known levels of air delivery as in item (b) in sea states 2 and 3. Trim will be recorded.

## 7.2 Auto Pilot

### Purpose

- \* To conduct calm water power tests to insure proper rigging of the control surfaces.
- \* To conduct calm water maneuvering tests to insure:
  - a) Adequate sensor inputs for height, roll, roll rate, pitch or heave;
  - b) Adequate auto pilot gain for response rate or degree;
  - c) Absence of backlash or extraneous inputs such as engine vibration affecting a heave accelerometer.
- \* To conduct rough water tests to:
  - a) Determine the effect of auto pilot gain upon the degree of platforming achieved with different wave lengths and heights;
  - b) The effect of auto pilot gain upon vehicle stability at different speeds and weights.

### Method

- 7.2.1 Calm water tests - same as Test No. 3.0.
- 7.2.2 Rough water tests - same as Test No. 4.0.
- 7.2.3 The following additional measurements are required on the same time basis as (a) and (b) above.

Heading  
Roll Rate  
Operator's Rudder Control Wheel Angle  
Auto Pilot Gain  
(Rudder Angle, Roll Angle, Rate of Turn)

## 7.3 Length to Beam Ratio

### Purpose

- \* To determine the effect of changing beam width on roll stability.
- \* To determine the effect on resistance, required installed power and high speed rough water characteristics.



**Method**

- 7.3.1 Roll stability tests will be conducted in accordance with Test Nos. 3.1, 3.15 and 4.2.
- 7.3.2 Power tests will be conducted in accordance with Test No. 3.5 through 3.14 and 4.1.

## 8.0 REFERENCES

- 8.1 USATECOM Regulation No. 705-11, Research and Development of Materiel, Authorized Testing Terminology, 29 March 1963, with change 1, 4 April 1963.
- 8.2 Wind Sea State Chart, Wilber S. Marks, Compiler; David Taylor Model Basin, Washington, D. C.; circa 1957.
- 8.3 Department of the Army, Army Regulations No. 705-5, Research and Development of Materiel, Army Research and Development, 15 October 1964.
- 8.4 Department of the Army, Army Regulations No. 700-20, Logistics, Type Classification of Materiel, 25 July 1963.
- 8.5 Department of the Army, Army Regulations No. 320-5, Dictionary of United States Army Terms, 28 February 1963, with change 1, 26 December 1963.
- 8.6 Department of the Army, U. S. Armor Board, Fort Knox, Kentucky, Test Manual, 22 April 1963.
- 8.7 High Surf Testing of the LVTPXD1-1; Final Report Project No. 65-07; Annex D (Engineering Test Plan) to OPORD 1-66. West Coast Branch (Amphibian Vehicle Division, Marine Corps Landing Forces Development Center, Marine Corps Schools, Quantico, Virginia)
- 8.8 Department of the Navy, OPNAV Instruction OP3900.3A dated 11 January 1961.

APPENDIX A  
HUMAN FACTORS ENGINEERING CHECK LIST  
FOR MILITARY TACTICAL WHEELED VEHICLES \*

## A 1.0

## VEHICLE DESIGN

A 1.1 Seats

Driver and crew seats are adjustable for tall and short men and are contoured to fit the back and buttocks of the average man.

A 1.2 Controls

- A 1.2.1 The steering control-operator seat relationship shall permit safe, easy, and comfortable driving.
- A 1.2.2 The control requires as few movements as possible.
- A 1.2.3 Successive control movements are inter-related; i.e., one movement passes easily into the next.
- A 1.2.4 Controls used in rapid sequence have uniform direction of motion.
- A 1.2.5 Control movements are consistent for all equipments which one operator uses.
- A 1.2.6 The method used to prevent accidental activation of the control, if any, does not increase the time required to operate the control to such an extent that it is unacceptable.
- A 1.2.7 Activation of the control does not obscure visual display or control markings.
- A 1.2.8 Controls such as clutches and foot throttles are located in such a manner that they can be operated easily without the driver having to assume uncomfortable body angles. Controls of this type are also capable of being operated easily when the driver is equipped with thermal boots.
- A 1.2.9 Foot throttles are so located that the driver, with minimum amount of movement and effort, can remove his foot from the throttle and apply the foot brake.
- A 1.2.10 The driver has the capability of applying the brakes easily when thermal boots are worn.
- A 1.2.11 The instrument panel is so located that it can be observed from the normal driving position.

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\* Ref. 8.6. Refer to the SOR etc. as a guide and to Manual of Standard Practices for Human Factors in Military Vehicle Design, August 1962, Aberdeen Proving Grounds, Technical Memo 21-62 or later editions in preparing check list and conducting tests.

- A 1.2.12 A master warning light is provided for notification when engine temperature, oil pressure, bilge water, etc. are above or below safe operating ranges.

A 1.3 Displays

- A 1.3.1 Information presented is necessary for the decisions or actions required of the operator.
- A 1.3.2 Information is presented in the most immediately meaningful form; i.e., no interpretation or decoding is required.
- A 1.3.3 Information is displayed to the accuracy required for decisions or actions by the operator, and preferably no more accurately than required.
- A 1.3.4 If scale interpolation is required, it does not introduce a probability for operator errors which are greater than the operator's task permits.
- A 1.3.5 Information for different types of activities; e.g., operation and maintenance, is not combined unless the activities require the same information.
- A 1.3.6 Information is current; i.e., lag is minimized.
- A 1.3.7 Failure in the unit is clearly shown or the operator is otherwise warned.
- A 1.3.8 A warning device is provided to indicate when the emergency brake is on.
- A 1.3.9 For bulk refuelers, instructions for operation are placed conspicuously on the equipment.
- A 1.3.10 Tire pressures are clearly indicated.

A 1.4 Miscellaneous

- A 1.4.1 Adequate means are provided for the driver to get in and out of the cab when wearing cold-weather clothing.
- A 1.4.2 Adequate means are provided for troops to mount the rear of trucks with minimum difficulty.
- A 1.4.3 Nonskid decking is provided for safety.
- A 1.4.4 OEM tools are located where they are easily accessible to drivers.
- A 1.4.5 Power-assist steering is provided for vehicles having a weight-carrying capacity of 5 tons and above.

- A 1.4.6 Tailgates on trucks, 2-1/2 tons and over, incorporate an equilibrator that slow their movements to the down position and assist their movement to the closed position.
- A 1.4.7 Safety straps are placed in vehicles that do not have doors on the driver and passenger side. They are also required for the safety of passengers in the cargo compartment.
- A 1.4.8 Whenever possible, trucks have drop sides for ease of loading. Means should be provided to permit ease of lowering and raising.
- A 1.4.9 For bulk refuelers, fire extinguishers are placed at an easily accessible location, and that location is one where fire is not likely to start.
- A 1.4.10 An adequate set of handholds is provided for safety.

## A 2.0

## MAINTAINABILITY DESIGN

A 2.1 Handles

- A 2.1.1 When possible, handles are provided on covers, drawers and components to facilitate handling.
- A 2.1.2 When handles cannot be provided, hoist and lift points are clearly marked.
- A 2.1.3 When possible, handles are located over the center of gravity to prevent the object from tipping while being lifted or carried.
- A 2.1.4 Handles are positioned so that they cannot catch on other units, wiring, protrusions, or structural members.
- A 2.1.5 The following dimensions are minimum for handles to be used by the ungloved hand:
  - (a) Weight to be lifted or moved is under 25 pounds:
    - Handles diameter: 1/4 - 1/2 inches
    - Finger clear: 2 inches
    - Handle width: 4 1/2 inches
  - (b) Weight to be lifted or moved is over 25 pounds:
    - Handle diameter: 1/2 - 3/4 inch
    - Finger clear: 2 inches
    - Handle width: 4 1/2 inches

**A 2.2 Covers, Cases and Access Doors**

- A 2.2.1 Method of opening a cover is evident from the construction of the cover itself. If not, an instruction plate is permanently attached to the outside of the cover.
- A 2.2.2 Hinges are used, where possible, to reduce the number of fasteners required.
- A 2.2.3 When a hinged cover is used, a space equal to the swept volume of the cover is provided; e.g., opening of the cover is not obstructed by bulkheads, brackets, etc.
- A 2.2.4 Structural members, other components, etc., do not interfere with removal of a cover.
- A 2.2.5 Provision has been made for adequate bonding of plastic or rubber stripping and seals, so that if a cover comes into contact with, or must slide over such material, the seal will not be damaged or the cover jammed.
- A 2.2.6 It is evident when the cover is in place but not secured.
- A 2.2.7 Where feasible, guides, tracks, and stops are provided to facilitate handling and to prevent damage to components.
- A 2.2.8 Access doors are hinged at the bottom if possible.
- A 2.2.9 When access doors must be hinged at the top, a support rod is provided to hold the cover open.
- A 2.2.10 Hinged doors or covers are provided with captive, quick-opening fasteners.
- A 2.2.11 If instructions applying to a covered unit are lettered on a hinged door, the lettering is properly oriented for reading when the door is open.
- A 2.2.12 A minimum number and type of fasteners are used, commensurate with requirements for compensating for stress, bonding, etc.
- A 2.2.13 When possible, the same size and type of fasteners are used for all covers, cases, and access doors.
- A 2.2.14 Maximum use is made of tongue-and-slot catches to minimize the number of fasteners required.
- A 2.2.15 Hand-operated fasteners requiring no tools are preferred; those requiring nonstandard tools should not be used.
- A 2.2.16 Captive nuts and bolts are used where feasible.

### A 2.3 Accessibility

A 2.3.1 Information placed at each access includes the following:

- (1) Nomenclature of items accessible through it
- (2) Warnings of hazardous or critical operations

A 2.3.2 Edges of accesses have internal fillets or other protection if they might otherwise cause injury to hands or arms.

A 2.3.3 Access provisions are located on easily accessible surfaces.

A 2.3.4 Components are not placed in recesses or located behind or under stress members, floor boards, seats, hoses, pipes, or other items which are difficult to remove.

### A 2.4 Reaching

Smallest allowable openings for one-hand tasks are as follows:

A 2.4.1 Inserting empty hand held flat: 2 1/2 by 4 1/2 inches

A 2.4.2 Smallest square hole through which empty hand can be inserted: 3 1/4 by 3 1/4 inches

A 2.4.3 Using 8 inch screwdriver with a 1 inch diameter handle: 4 by 4 inches.

A 2.4.4 Inserting drawer or electronic assembly grasped by handles on front, into opening: 1/2 inch clearance on each side of assembly.

A 2.4.5 Reaching through opening with both hands to depth of 6 to 25 inches: width, three-quarters the depth of reach; height, 4 inches.

A 2.4.6 Reaching in full arm length (to shoulders), straight ahead, with both arms: width, 20 inches; height, 4 1/4 inches.

### A 2.5 Location of Replaceable Components

A 2.5.1 Large components which are difficult to remove are mounted so that they do not prevent access to other components.

A 2.5.2 Components are located so that each replacement unit can be removed through a single access panel.

A 2.5.3 Components are placed to allow sufficient space for use of test equipment and other required tools without difficulty or hazard.

A 2.5.4 All throwaway components are accessible without removal of other components.

- A 2.5.6 Delicate components are so located or guarded that they will not be damaged while the unit is being handled or worked on.
- A 2.5.7 Components are located so that blind adjustments are not necessary.
- A 2.5.8 Components of the same or similar form, such as seals, are mounted with a standard orientation throughout, but are readily identifiable and distinguishable.
- A 2.5.9 Equipment is modularized so that rapid and easy removal and replacement of malfunctioning modules or components can be accomplished by one technician.
- A 2.5.10 Components can be checked and adjusted separately and then connected together into the system with minimum adjustment.

#### A 2.6 Component Mounting

- A 2.6.1 Whenever possible, components are so located that no other equipment must be removed to gain access or to remove them.
- A 2.6.2 If it becomes necessary to place one component behind another, the component requiring less frequent access is in the rear.
- A 2.6.3 Components frequently removed for checking from their normal installed position are mounted on roll-out racks, slides, or hinges.
- A 2.6.4 Limit stops are provided on roll-out racks and drawers; override of these limit stops is easily accomplished.
- A 2.6.5 Field removable components are replaceable with common handtools.
- A 2.6.6 Components are mounted to the housing rather than attached to each other so only the component to be replaced has to be removed.
- A 2.6.7 Removal of any replaceable component requires opening or removal of a minimum number of covers or panels (preferably one).
- A 2.6.8 Components are laid out so that a minimum of place-to-place movement by the operator is required during checkout.
- A 2.6.9 Components are located and mounted so that access to them may be achieved without danger to personnel; e.g., from electrical charge, heat, sharp edges and points, moving parts, chemical contamination.
- A 2.6.10 Access to units maintained by one operator do not require removal of equipment by a second higher-skilled operator.



## A 2.7 Conductors, Cables and Conduits

- A 2.7.1 Long conductors, cables, and conduits internal to equipment, are secured to the chassis by cable clamps.
- A 2.7.2 Cables are long enough so that each functioning component can be checked in a convenient place or, if this is not feasible, extension cables are provided.
- A 2.7.3 Cables are long enough to permit jockeying or movement of components when it is difficult to connect or disconnect other cables.
- A 2.7.4 Cables and conduits are routed so they cannot be walked on or used for handholds.
- A 2.7.5 Cables and conduits are easily accessible for inspection and repair.
- A 2.7.6 Cables and conduits are so routed that they need not be bent or twisted sharply or repeatedly.
- A 2.7.7 If feasible, individual conductors of all cables, either single-or multi-conductor, are color coded their entire length.

## A 2.8 Connectors

- A 2.8.1 One-turn or other quick-disconnect plugs are used.
- A 2.8.2 When dirt and moisture are a problem, plugs have an attached cover.
- A 2.8.3 Connectors are located far enough apart so that they can be grasped firmly for connection and disconnection.
- A 2.8.4 Rear of plug connectors is accessible for test and service, except where this is precluded by potting, sealing, etc.
- A 2.8.5 Plugs or receptacles are provided with aligning pins or other alignment devices.
- A 2.8.6 Plugs are designed so that it is impossible to insert the wrong plug in a receptacle.
- A 2.8.7 Socket rather than plug contacts are "hot".
- A 2.8.8 Connectors and their associated labels are positioned for full view by maintenance personnel.
- A 2.8.9 Connecting plugs and receptacles are identified by color or shape or other acceptable means.
- A 2.8.10 Plugs and receptacles have painted stripes, arrows, or other indications to indicate proper insertion of aligning pins.

## A 2.9 Test Points

- A 2.9.1 Test points to determine that a unit is malfunctioning are provided.
- A 2.9.2 Appropriate test points are provided when a component is not completely self checking.
- A 2.9.3 First echelon test points are so located and coded that they are readily distinguished from higher echelon test points.

## A 2.10 Fuzes and Circuit Breakers

- A 2.10.1 Fuzes and circuit breakers are so located that they can be easily seen and quickly replaced or reactivated.
- A 2.10.2 Fuze replacement is not hampered by other components.
- A 2.10.3 No special tools are required for fuze replacement.

## A 2.11 On-Equipment Tools

- A 2.11.1 Variety of tools is held to a minimum.
- A 2.11.2 As few special tools as possible are required.
- A 2.11.3 Tools are of dull finish to avoid glare in strong light.
- A 2.11.4 Speed and ratchet-type tools are provided when necessary.
- A 2.11.5 Nonsparking tools are provided for use in an explosive atmosphere.

## A 2.12 Lubrication

- A 2.12.1 Equipment containing mechanical components either has provision for lubrication without disassembly or does not require lubrication.
- A 2.12.2 When lubrication is required, the type of lubricant to be used and the frequency of lubrication is specified by a label at or near the lubrication point.

## APPENDIX B

### INSTRUMENTATION

#### B 1.0 GENERAL

##### B 1.1 Requirements

The instrumentation for the water phase of engineering tests is required to record power data and motion data primarily, and certain other parameters as specified in the handbook. The power data normally include vehicle speed, thrust, torque and r.p.m. and the motion data normally roll, pitch and acceleration.

The vehicles present an environment of spray, humidity, shock and vibration, and the instrument systems must be designed with due attention to those problems.

For the simple analysis procedures used in the programs, all recordings are normally made on oscillograph recorders. Data for A.D.P., such as accelerations, may be a requirement from time to time and recording is then made on magnetic tape.

##### B 1.2 Instrument Cabin

Where possible a separate instrument cabin is used, such as a Heil hut, and as much as possible of the instrumentation is mounted in this (see Figure B-1). The cabin provides working space for the instrument operator and protection against spray. Mounting the cabin on shock mounts also provides a measure of protection against shock and vibration. An interior view of a typical cabin is shown in Figure B-2. A CEC 5119 50 channel recorder is shown in the lower right hand corner and a signal conditioning rack in the center.

The signal conditioning rack is itself mounted on shock mounts in the cabin and is sealed to give humidity protection. An internal blower and dessicant tray maintains dry conditions in the rack.

The cabin can be moved readily from one vehicle to another or to the shop as required.

##### B 1.3 Instrument Rack

Figure E-3 is a view of a typical instrument rack. The upper three drawers are signal conditioning racks and include zero and scale setting controls. The function control provides simulated signals through each system from resistance (R cal) or frequency standards. The two principle signal conditioning systems are bridge circuits and pulse rate integration circuits. (See Figure B-4.)

Other drawers are for amplifiers, power supplies, gyroscope control and dehumidifier.

#### B 1.4 Calibrations

System calibrations are carried out before and after a test series on each of the channels, in which the original parameter is varied and recordings made of both the applied parameters and measured parameter. From these, linearity is checked and the precise values of the R. cals found. These are chosen beforehand to represent 1/2 and full scale in the measured quantity. Figure B-5 is a blank system calibration sheet.

#### B 1.5 Typical Signal Conditioning Console

To assist contractors in planning test programs a detailed description of an instrumentation console used in the ARCK and LVW testing programs is provided.

##### B 1.5.1 Requirements

Due to the limited space available for instrumentation in both the ARCK and LVW, it was necessary to design and construct a special instrumentation rack in order to meet all the test program requirements. These requirements were as follows:

- (a) A console package 48" X 26" X 14";
- (b) Signal conditioning channels for information generated by strain gage bridge-type transducers;
- (c) Signal conditioning channels for information generated by potentiometer-type transducers;
- (d) Signal conditioning channels for information generated by frequency generating type transducers;
- (e) Isolated, regulated power supply capable of powering items b, c, d, g, h and i;
- (f) Filter-amplifiers for noisy information channels;
- (g) Isolated, individual supplies for each amplifier channel;
- (h) Control circuits for gyros used to gather motion data;
- (i) Signal conditioning channels for temperature information;
- (j) Ease of operation, modification and maintenance;
- (k) Operational capability in extremes of vibration, shock, humidity, and spray conditions.

These requirements were successfully met in the ARCK Rough Water Tests at Little Creek, Virginia. Similar Rough Water Tests are in progress with the LVW at Camp Pendleton, California. The following is a detailed description of how the above requirements were met (each vehicle has its own console; identical except where indicated). Figure B-6 is a block diagram.

##### B 1.5.2 Strain Gage Circuits

The ARCK and LVW programs required 11 and 13 strain gage information channels respectively. The channels are packaged in two 19" X 5 1/4" panel-drawers per console (panels 2 and 3), eight channels per drawer.

### B 1.5.3 Check Out Shielding and Fusing

Each channel has controls for fused power on/off, zero balance, four electrical calibration points, polarity reversal, and span of output. There are also two monitoring switches and a monitoring meter for quick system checks on any channel.

Electrical connections are made for input (transducers) by a 50 pin amphenol connector, output by a 25 pin amphenol connector, and power in by a Bendix 3 pin connector. This allows for easy removal of the panels from the console (Figure B-4).

Spurious noise and cross-talk between channels were minimized by originating the shield at the individual channels output and continuing it through all cables in the channel system. The shield was not terminated at the transducer to avoid ground loops.

### B 1.5.4 Potentiometer Circuits

The ARCK and LVW programs required 2 and 4 potentiometer signal conditioning channels respectively. These are packaged in one 19" X 5 1/4" panel-drawer per console (panel 1), eight channels per panel. These channels have the same operational functions as described above.

### B 1.5.5 Frequency

The ARCK and LVW programs required 3 and 2 frequency generated channels respectively.

These channels are packaged in one 19" X 3 1/2" panel-drawer (panel 7) per console containing pulse rate integrators (manufactured by Anadex) with associated circuitry for input-output matching, calibration, and span adjustments.

### B 1.5.6 Main Power Supply

The isolated, regulated power supply requirements were 180 watts at 1% line/load regulation. These were satisfied by an Abbot transistorized power supply, Model #CL-24D-24.7A<sup>+</sup> (panel 5).

### B 1.5.7 Filters and Amplifiers

In both the ARCK and the LVW, certain channels (torque and thrust) were noisy at 30 - 80 cps due to prop shaft rotation. This noise was avoided through the use of a passive filter in series with a D.C. preamplifier.

In the ARCK program, the amplifier was used strictly as an impedance matching device (gain = 1.2 - 2); in the LVW program the thrust channels required amplification as well as filtering.

The amplifier/filter combinations were packaged in one 19" X 3 1/2" panel-drawer per console (panel 4), with eight filter/amplifier channels per panel.

Each channel consists of modified Burr Brown model number 1632 D.C. preamplifier with a total drift and nonlinearity of not more than 3% of full scale (short to medium term \*).

The filters were installed in the amplifier packages to reduce noise and physical volume of signal.

Eight amplifier/filter channels were provided. Due to their linearity characteristics and input-output configuration, these amplifiers required isolated 1/2% line/load regulated power supplies to avoid ground loops and non-linearity.

Sprague Dynacor Division built a compact eight channel power supply to Selwood Research, Inc. specifications which Selwood Research, Inc. packaged in a 19" X 3 1/2" panel, one per console. No cross talk or noise has been observed to date, nor have there been other failures.

#### B 1.5.8 Gyros

The ARCK program required one gyro; the LVW required two. The power and caging controls and indicators are included in the main power supply panel (panel 5). The power/gyro control circuits have proven totally reliable.

#### B 1.5.9 Temperature

Original plans called for gathering temperature information on the ARCK and LVW. Due to the reduced test time, these plans were revised and no temperatures were taken. The thermocouple reference junction was then removed from the console to avoid undue environmental deterioration. These panels contain 24 referenced thermocouple junctions compatible with all commercially manufactured thermocouples.

The temperatures of the LVW thrust bearings and torque meter were to be monitored. This was accomplished by modifying the strain gage bridge channels (22 - 24) to accommodate thermistor transducers.

#### B 1.5.10 Set Up Time and Maintenance

The instrumentation console was designed for ease of operation and adjustment. Set up time per channel is approximately two minutes. (Typical turn on to operation time for the ARCK was twenty minutes for twelve channels of information.)

The panels are equipped with electrical connectors so that they may be easily detached from the console for maintenance purposes.

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\* Medium term effects were avoided by limiting test runs to five minutes and re-zeroing the amplifiers.

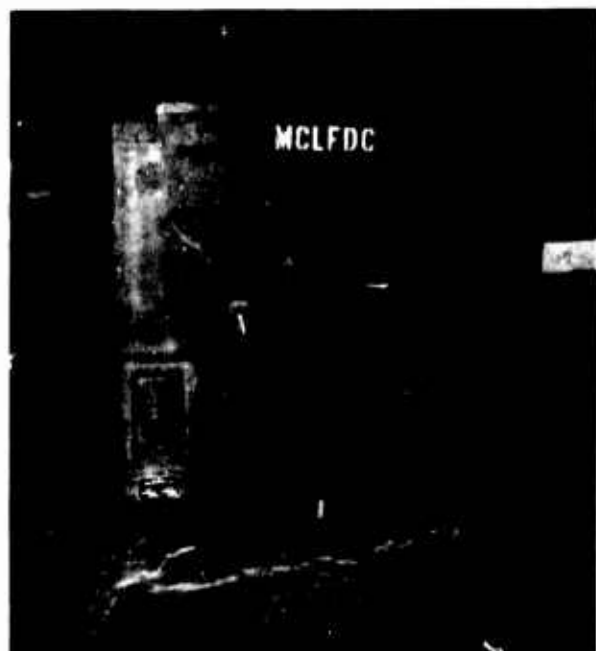
Connections between the console and the remainder of the system were made by means of connectors mounted on the right and left sides of the console. The left side consists of 3, 4, and 6 pin Bendix pigmy connectors for input to/from the transducers. The right side (output) consists of 3 pin Bendix connectors for output to galvos and input to amplifiers, and 6 pin Bendix connectors to gyros for power and control (see Figure B-4.)

#### B 1.5.11 Environmental Protection

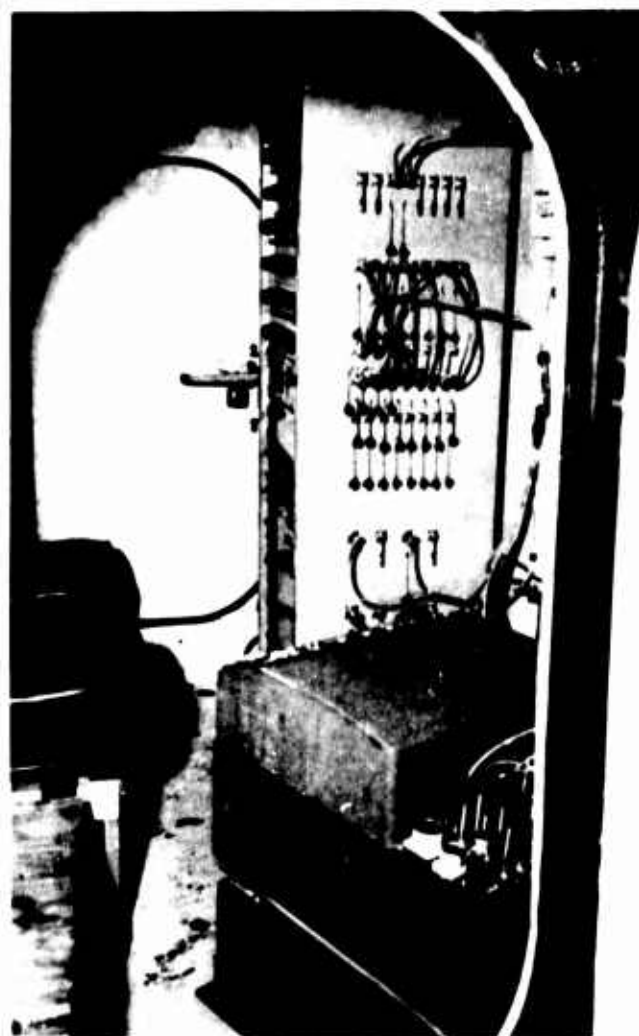
The environment to which the console of the ARCK was subjected included frequent and prolonged 4g impact loads, vibration, high humidity and spray. During the six weeks of rough water testing, only one minor failure was attributed to the console itself.

The wiring was done in accordance with NASA standards. Each panel was gasketed against spray and moisture, and the lowest panel holds a dehumidifying chamber containing silica gel which filters blown air.

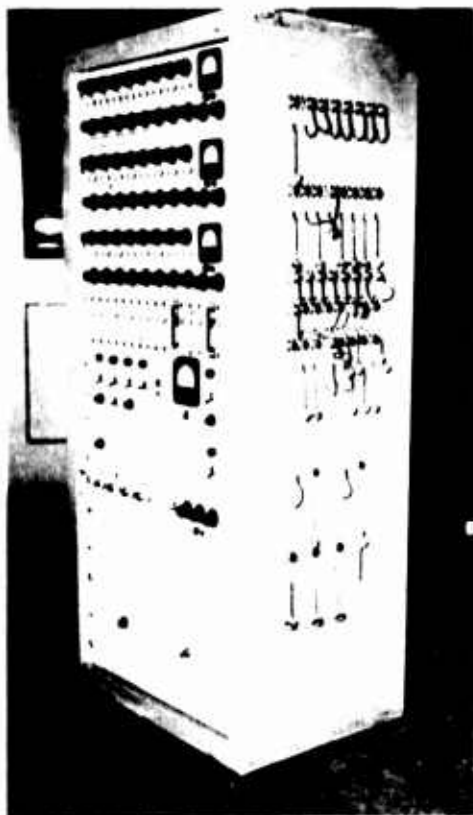
The entire console was vertically shock mounted with 70 pounds capacity shock mounts and horizontally and laterally secured with rubber mounted steel bars. Deterioration of the console and components during the twelve months test program was minimal.



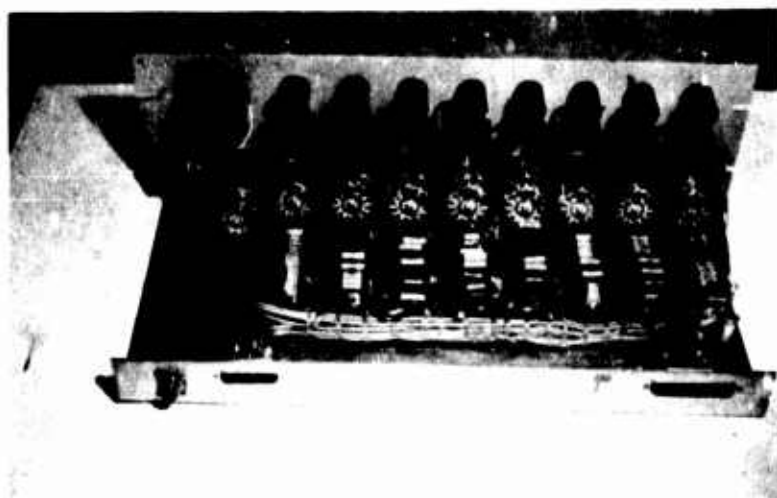
HEIL HUT  
FIGURE B-1



INTERIOR OF A TYPICAL CABIN  
FIGURE B-2



TYPICAL INSTRUMENTATION RACK  
FIGURE B-3



TYPICAL DRAWER  
FIGURE B-4



VEHICLE:		SYSTEM:		DATE:		
TRANSDUCER:		TYPE NO:		SERIAL NO:		
LOCATION IN VEHICLE:						
SIGNAL CONDITIONING CHANNEL:						
AMPLIFIER NO:						
GALVO. NO:		TYPE:				
METER TYPE:		SERIAL NO:				
<u>METHOD OF CALIBRATION:</u>						
% F.S. ACCURACY:						
<u>SOURCE CALIBRATION:</u>						
% F.S. ACCURACY:						
NOMINAL APPLIED PARAM.	CORRECTED APPLIED PARAMETER	CEC TRACE NO.	METER READ OUT	CEC DEFLECTION IN.	SCALE FACTOR ( )	R CAL DATA
Zero						
R Cal 1						R Cal 1
R Cal 2						CEC: READING: METER:
R Cal 3						
R Cal 4						R Cal 2
Zero						CEC: READING: METER:
						R Cal 3
						CEC: READING: METER:
						R Cal 4
						CEC: READING: METER:
Zero						
					AVERAGE	

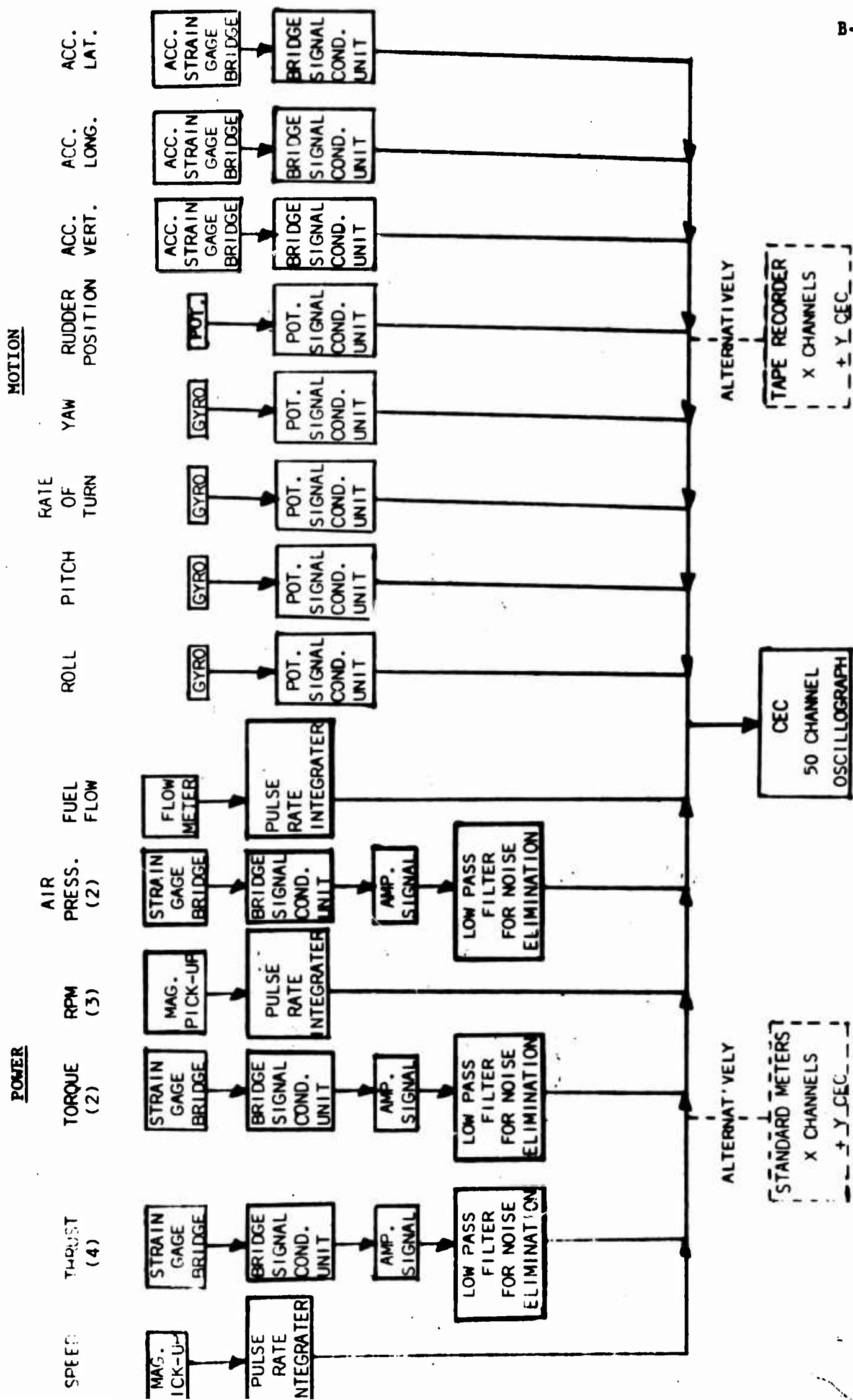


Figure B-6 - Block Diagram of Signal Conditioning Console

## B 2.0 SPEED MEASUREMENT

### B 2.1 Requirements

The analysis requires the measurement of effective power in the water for each of the steady test conditions, and also during acceleration through the transition from displacement to planing mode. A reliable vehicle mounted speed measuring system is important to avoid being tied to a fixed transit course as well as for the acceleration data. The system has to work in rough water, and be as little affected by severe pounding and rough handling as possible.

E.H.P. is required to  $\pm 5\%$  to give sufficient discrimination and both speed and thrust (to determine drag) are required preferably within  $2\frac{1}{2}\%$ .

### B 2.2 Systems

#### B 2.2.1 Pitot

This system has the merit of simplicity and a number of low cost units reading out on pressure gages are available. The pitot tube is mounted in a location where the vertical velocity during pitching and flow distortion due to the hull are as little as possible. Troubles are experienced with maintaining the correct water level in the damping chamber, clogging and vulnerability of the tube. It is usually important to have both low speed and high speed systems and several fitted in each range to avoid delays. With care, good results have been obtained in calm water.

A pressure transducer can be used, mounted in the vehicle as close to the pitot head as possible, and damping performed electrically. This permits recording.

#### B 2.2.2 Electromagnetic

An e.m.f. is produced when sea water, a conductor, passes through a magnetic field. This principle is used in a ship speedometer since the e.m.f. depends on the speed of the flow. The system is accurate when compensations are made to increase the signal. Owing to size and cost the speedometer is more frequently used in ship applications.

#### B 2.2.3 Rod

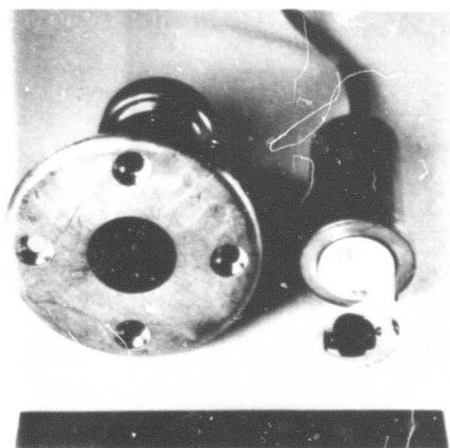
The resistance of a rod moving through water varies with speed. This principle is used in a speedometer in which a rod projects from the hull and the bending moment at the point of support is detected electrically. One maker is Kenyon.

#### B 2.2.4 Doppler Systems

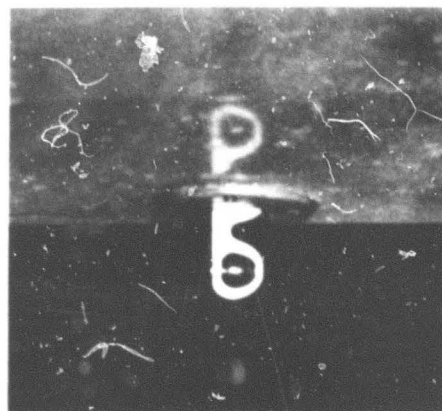
Ultrasonic and radar doppler systems have been used for speed measurement. Gulton Industries makes an ultrasonic system. The radar system is frequently chosen for A.C.V.s, but for rough water work pitching tends to reduce the accuracy.

#### B 2.2.5 Rotary Impeller

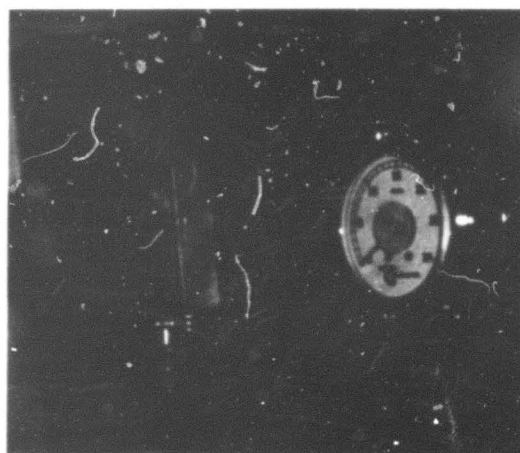
The most satisfactory system found for high speed amphibians uses the rotary impeller (see Figure B-7). In this, the sensor is a small impeller mounted on a small retractable fin below the hull which sends out a small voltage pulse at each revolution (see Figure B-8). Numerous versions are available. The Triton system (Figure B-9) has given no trouble in sea state 3 and has recorded speeds up to 30 knots with a scatter in calibration not more than 2% at the high end of the scale. Environmentalisation is good with a hermetically sealed circuit box fitted with an indicating dessication system. Other makes and trade names are Rite Knot, Navilog, Walker and Accuknot. See Test Number 3.3.



ON IMPELLER AND HULL HOUSING  
FIGURE B-7



IMPELLER INSTALLATION  
FIGURE B-8



INSTALLATION OF TRITON AMPLIFIER AND METER  
FIGURE B-9

## B 3.0 THRUST

### B 3.1 Requirements

The analysis of vehicle drag, and hence E.H.P., requires measurement of propeller thrust. The requirement for E.H.P. to  $\pm 5\%$  means that the thrust should be known to 2 1/2%. Thrust data is required for all the steady speed test conditions, and for the thrust transient in going through the transition from displacement to planing speeds. Damping is desirable to smooth the signal from variations induced by pounding, and can be introduced electrically.

### B 3.2 Systems

#### B 3.2.1 Hydraulic

In this form the thrust bearing is supported longitudinally by means of a set of bellows or cylinders containing hydraulic oil. Figure B-10 shows a piston type unit, lower left, installed in the ARCK. The thrust is converted into hydraulic pressure which is recorded on pressure gages or sensed by pressure transducers as shown in Figure B-11. The latter signal is transmitted to its CEC recorder.

The pump in the center of Figure B-11 and the indicator lights on the right are used to line up the shaft longitudinally so that it is clear of end stops.

#### B 3.2.2 Indirect Strain Gage

Gages can also be applied to structure supporting the thrust bearing provided a suitable load path can be identified. In some cases, tension on a gear box housing, such as in the LVHX-2, has been found satisfactory. In other cases, shear on supporting lugs of the thrust bearing housing, such as in the LVW, has proved measurable although overdesign has meant a low signal level, which is common to most examples of this type of system.

Mechanical amplification of signal level was found possible in the ARCK on the reserve thrust system, where a rigid cross beam was mounted above the beam carrying the thrust bearing (Figure B-10). The small relative movement of the lower beam set up large shear stress in the shear web of the transducer which was mounted near the middle of the beam. (Figure B-10a). Figure B-12 shows the strain gage transducer prior to mounting on the beam.

### B 3.3 Strain Gage Protection

Thrust measurement has provided more than one case where strain gages are underwater. Adherence of many of the commercially available sealing compounds to aluminum alloys tends to be unreliable, but a technique based on Dean Mill's "shim cap" method has been found satisfactory.

After attaching the gages, terminal strips and water proof leads, the installation is coated with Budd GW2 and GW5. After a preheat, Mobil 3100 wax is applied and trimmed. Two coats of Bean gagekote 5, one followed by a shim cap, are applied while the top coat is still wet. Between successive degreasing and cleaning, further coats of gagekote 5 are applied and a final coat of silicone rubber R. T. V. applied. A number of these steps are shown in Figures B-13 to B-17.

Figure B-13 shows a thrust bearing housing of the LVW cleaned ready for strain gaging.

Figure B-14 shows the gages ready to be cemented in place.

Figure B-15 shows the gages installed and connections.

Figure B-16 shows the molded clamping blocks for applying the equal pressure to the gage installation.

Figure B-17 shows the wax coating during application and prior to fitting the shim cap. The shim cap is a thin piece of soft aluminum contoured to suit the wax coated strain gages and electrical leads. The outer edges are carefully cleaned free from wax to permit bending with epoxy cement to the aluminum thrust block. The whole assembly is then covered with epoxy resin. After this is allowed to dry, a final coating of silicon rubber is applied over the whole assembly.

### B 3.4 Calibration

See Test Number 3.12. Figures B-18 through B-20 show bollard pull tests in progress. The thrust unit is being calibrated against both a calibrated strain gage load cell adjacent to the test item (Figure B-19) and a hydraulic load cell adjacent to the bollard (Figure B-20).

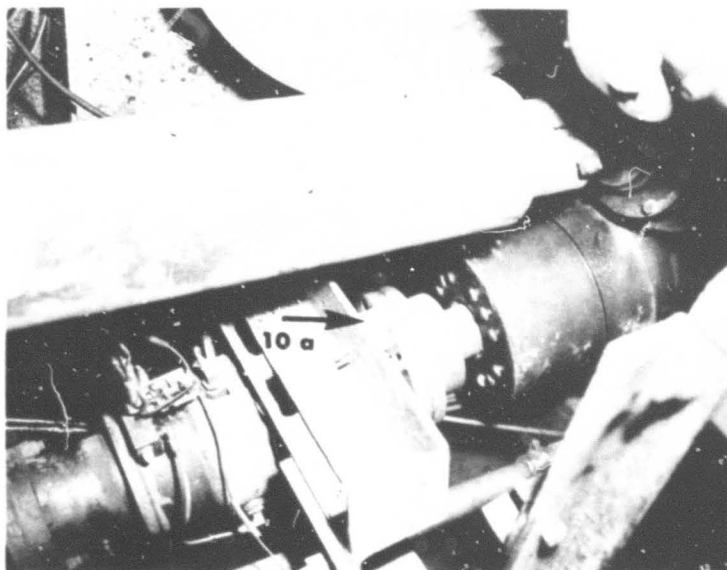


FIGURE B-10 PISTON UNIT ON ARCK

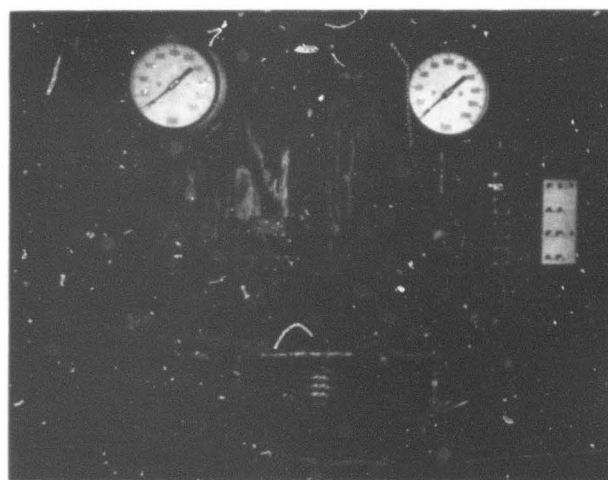


FIGURE B-11 PRESSURE GAGES

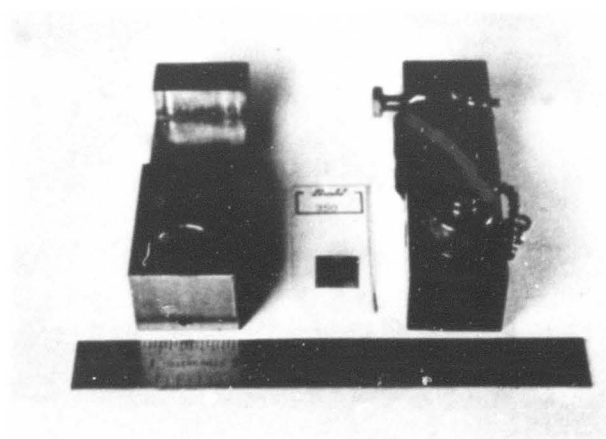
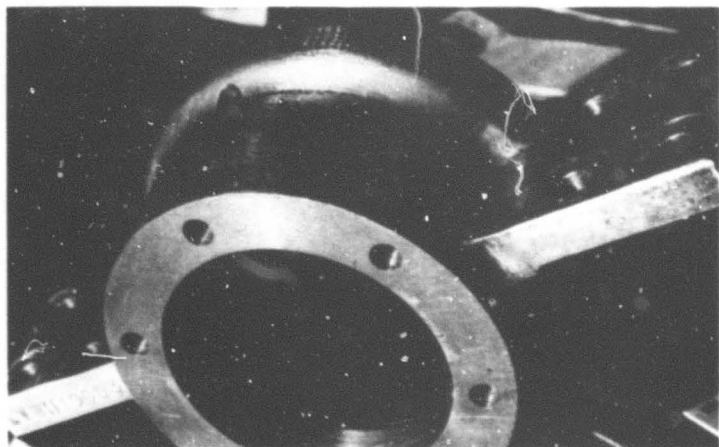


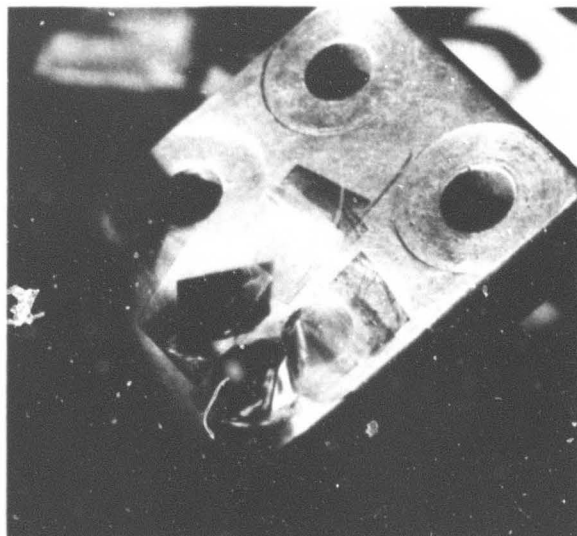
FIGURE B-12 STRAIN GAGE TRANSDUCER





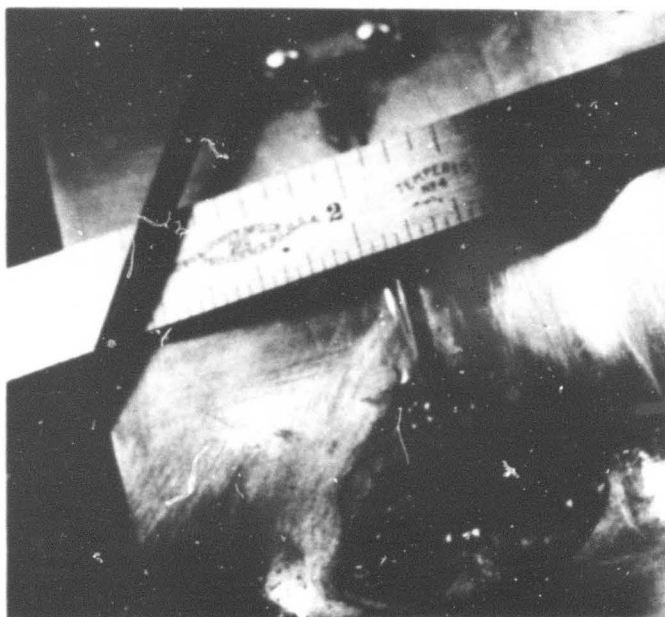
THRUST BEARING HOUSING

FIGURE B-13



STRAIN GAGES BEFORE PLACEMENT

FIGURE B-14



INSTALLED GAGES AND CONNECTIONS

FIGURE B-15



MOLDED CLAMPING BLOCKS

FIGURE B-16



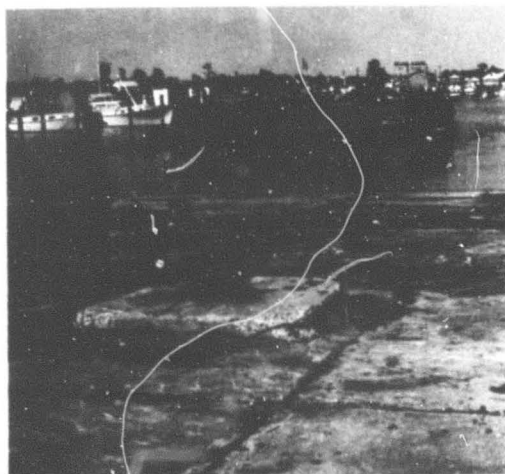
WAX COATING DURING APPLICATION

FIGURE B-17



BOLLARD PULL TEST

FIGURE B-18



CALIBRATED STRAIN GAGE LOAD CELL

FIGURE B-19



HYDRAULIC LOAD CELL

FIGURE B-20

## B 4.0 SHAFT R.P.M.

### B 4.1 Requirements

Shaft rpm is required for determination of shaft horse power. Knowing effective horse power, the propeller efficiency can be found during each of the tests. R.P.M. is required to  $\pm 2\%$  of full scale in order to find S.H.P. to  $\pm 5\%$ . Analysis of the propeller coefficients using this parameter may be conducted in order to observe possibilities of improvement in matching between the propeller and power plant, or in the propeller dimensions.

### B 4.2 Systems

Frequently used systems for rpm include voltage generating transmitters and pulse generating transmitters.

Since pulses can be transmitted with somewhat greater reliability than a voltage level, the pulse system is generally chosen for instrumentation. Pulse rate integrator modules with response characteristics better than  $\pm 1/2\%$  of full scale are available. Figure B-21 shows a typical Anadex pulse rate integrator. Figure B-22 shows an example of a pick up installed in the oil filter hole of a "V" drive gear box on the ARCK.

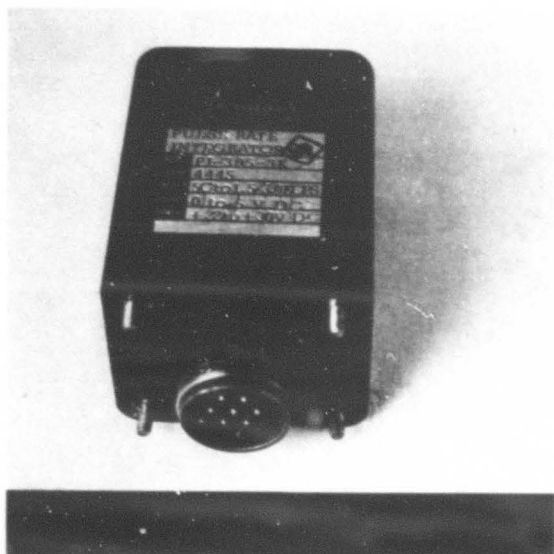
Figure B-23 shows a pulse transducer which is energised by teeth from the gear wheel mounted on the shaft (Figure 24).

### B 4.3 Calibration

Calibration of rpm channels is carried out by running the shaft at a series of steady speeds and counting pulses by means of a photo cell and counter over a period of ten seconds for each speed. A series of white marks round the shaft activate the photo cell and the average rpm is calculated.

The trace on the oscillograph is then averaged and a calibration curve drawn up from the data points.

Before and after the calibration runs, the frequency cals are shown on the oscillograph trace.



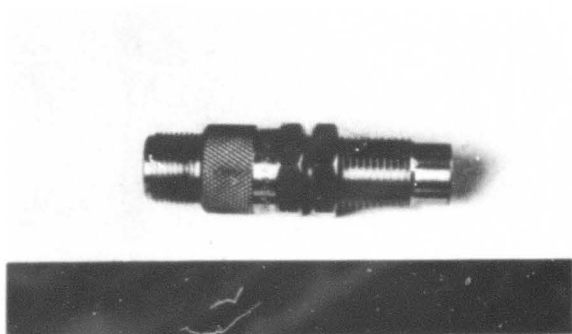
PULSE RATE INTEGRATOR

FIGURE B-21



PICK UP INSTALLED ON "V" DRIVE GEAR BOX

FIGURE B-22



PULSE TRANSDUCER

FIGURE B-23



INSTALLED PULSE TRANSDUCER

FIGURE B-24

## B 5.0 TORQUE

### B 5.1 Requirements

Analysis of the propeller characteristics during the tests, and measurement of S.H.P. requires the determination of torque on each shaft. For S.H.P. to  $\pm 5\%$  of maximum, torque is required to about  $\pm 3\%$ . Damping requirements are similar to those for the thrust system.

### B 5.2 Torque Systems

For finding propeller characteristics, the torque is preferably measured at the propeller end of the drive train. Allowances can be made for gear box losses in determining the power plant output.

Torque indicating systems can sometimes be based on strain gages mounted on the shaft and the power and signal leads taken through slip rings also specifically installed on the existing shaft. (Figure B-25). Two four-arm bridges are desirable with the axis of each gage mounted at  $45^\circ$  to the axis of the shaft, one bridge to act as reserve.

The shaft can sometimes be replaced by a commercial variant being bolted between flanges in the shaft. Figure B-26 shows one of two B.L.H. A30 torque units installed in the ARCK and this unit gave satisfactory service after initial sealing difficulties were overcome. In this case flexible couplings were provided in separate bearings at each end to remove stresses due to bending moments.

Another system is the use of steep vertical ball splines to translate the torque into a thrust in a self contained housing. The thrust can then be recorded by a hydraulic system with bellows and pressure gages or transducers.

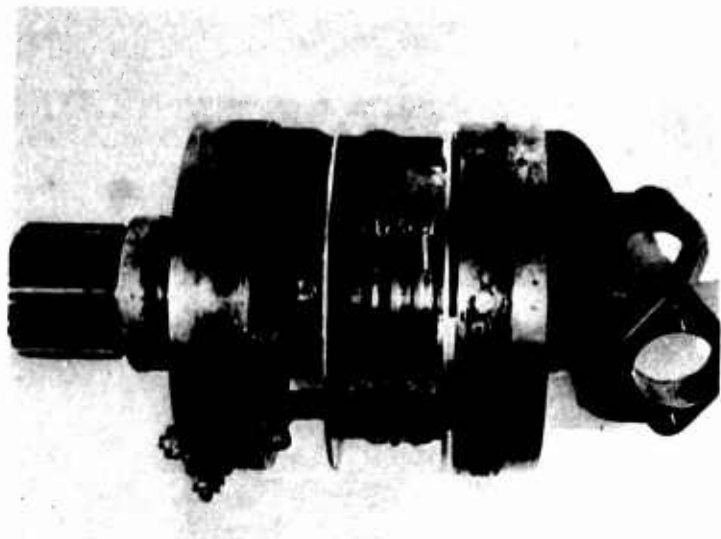
Figure B-27 is yet another version used in the limited space available on the LVW where the signal was taken out of the end of the shaft through a miniature slip ring assembly.

### B 5.3 Calibration

The torque unit can be removed from the vehicle, and torque calibration performed on a rig in the laboratory. A measured torque is applied by means of a cross bar and load cells, and the read out plotted against applied torque to give the calibration curve.

The R cals used in the measurement circuit are at the same time identified by putting them into circuit with zero torque applied.

Figure B-28 shows a calibration being performed in the laboratory.



TORQUE UNIT SPECIALLY  
INSTALLED ON EXISTING SHAFT

FIGURE B-25



BLH A30 TORQUE UNIT  
INSERTED IN A SHAFT

FIGURE B-26



MINIATURE SLIP RING ASSEMBLY  
FOR INSTALLING IN END  
OF SHAFT WHEN EXPOSED

FIGURE B-27



LABORATORY TORQUE CALIBRATION

FIGURE B-28

## B 6.0 ACCELEROMETERS

### B 6.1 Requirements

The analysis of motion characteristics requires the measurement of acceleration at the bow, center of gravity and the stern in the vertical direction with reference to the vehicle. Certain other positions and directions are chosen from time to time for specialized analysis, and it is usual to record surge acceleration and sometimes lateral acceleration.

The crew compartment on some vehicles is close enough to the bow for the one bow accelerometer to be sufficient for crew environmental studies, and the loading area is frequently centered closely above the center of gravity.

Plus or minus 2g accelerometers have given sufficient range at the center of gravity and  $\pm 5g$  accelerometers were found to be suitable at the bow of the ARCK.

### B 6.2 System

Denner, Statham and C.E.C. among many others make accelerometers, and strain gage types have been found satisfactory. The mounting is as rigid as possible to the vehicle framework to avoid spurious readings from the interconnection but it is difficult to remove noise arising from the vibration and deflection of the structure locally. Knowledge of the local natural frequencies, which show up on the record, help in the analysis stage.

The standard strain gage signal conditioning system is used. See paragraph B 1.5.

Figure B-29 shows a C.E.C. accelerometer and weatherized housing.

### B 6.3 Calibration

System calibration is carried out by using static inversion of the transducer to give a change of -2g and placing it on its side to give -1g, using the system in the vehicle. The R cal values are then determined. Linearity and frequency response may be checked in the laboratory on a shaker table.

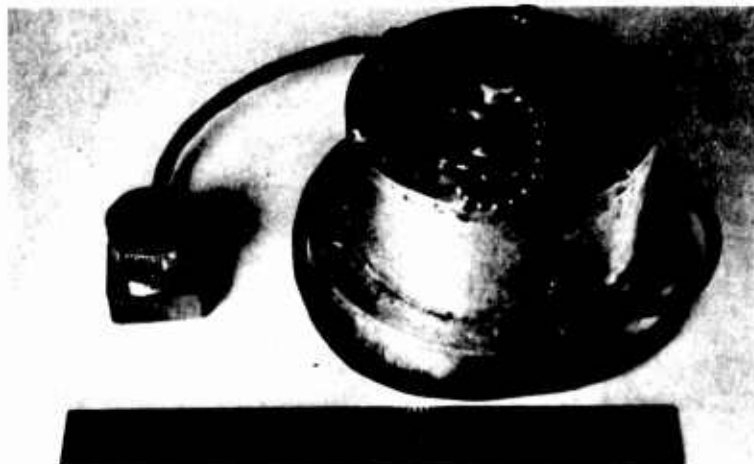


FIGURE B-29 CEC ACCELEROMETER AND WEATHERIZED HOUSING



## B 7.0 ROLL AND PITCH

### B 7.1 Requirements

The record of roll and pitch angle is analysed to assess stability of the vehicle under each of the test conditions. Whereas the static metacenter test shows the righting moments available under various angles of heel, in displacement mode the dynamic test gives the response at planing speeds to the overturning couple. The second derivative of the angle allows the overturning couple to be found at any given time as required. (The moments of inertia can be found by testing or calculation.) For the assessment required, a factor such as peak roll in a fixed aperture of wave impacts, or the statistical distribution of rolls in a given time period, is sufficient. Much the same goes for pitch angle, except that the mean pitch angle is significant as average trim and the statistical analysis uses variation of pitch on either side of this value.

A more comprehensive display of roll and pitch characteristics is given by cumulative probability curves, and these may be arranged to show frequency.

### B 7.2 System

An Iron Fireman Inc. N3200 roll and pitch gyro has been used and found satisfactory. This has a potentiometer system and the standard potentiometer signal conditioning system is used.

Mounting requires care so that the gyro does not receive excessive shock while remaining at a steady angle to the vehicle (see Figure B-30). A location between the center and aft end of the vehicle is preferable.

### B 7.3 Calibration

The gyro is calibrated on an inclination table in the laboratory. The plot of applied angle against output is checked for linearity, and erection and drift ratios are measured.



FIGURE B-30 ROLL AND PITCH GYRO ON MOUNTING

## B 8.0 FUEL FLOW

### B 8.1 Requirements

Fuel flow measurement in conjunction with the S.H.P. determination provides the specific fuel consumption curve for the power plant installation. From this the range of the vehicle at different cruising speeds may be found for a given tank capacity, and the overall thermal efficiency can be measured for different atmospheric conditions, power out puts and time since the last maintenance.

### B 8.2 Systems

A preferred system is a small turbine impeller mounted in the fuel line giving a frequency signal proportional to flow. Cox and Potter are typical manufacturers. Figure B-31 shows the Cox fluid flow transducer.

The frequency signal drives a pulse rate integrater in one of the frequency signal conditioning channels in the instrumentation rack and the analog output records on the oscillograph recorder or is displayed on a meter.

Care must be used to ensure that the transducer is not placed in the fuel pump outlet line when a fuel by pass valve is used further down the line.

### B 8.3 Calibration

Calibration may be carried out in the laboratory using a metering positive displacement pump driven by a synchronous motor. A gear change box provides five or six steady flow rates in the range of flows to be encountered during the tests, and the flow is measured by taking the time by stop watch to fill a measuring flask or vessel of known value.

The temperature of the fuel should be held as close as possible to that of fuel passing the transducer when mounted in the vehicle, to avoid errors due to viscosity.

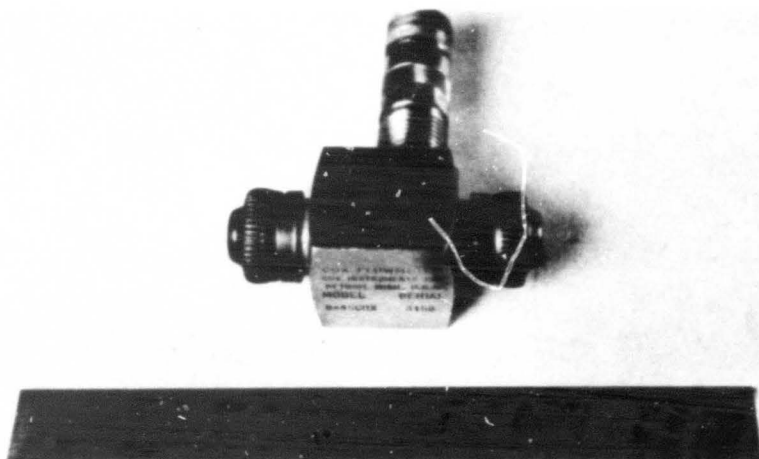


FIGURE B-31 COX FLUID FLOW TRANSDUCER

## B 9.0 AIR FLOW

### B 9.1 Requirements

Certain vehicles, such as the ARCK, utilize air lubrication, an air bubble, or ground effect. Power used in this supply, and the measurement of flow characteristics of the air system, are necessary in determining total power required to operate the vehicle, and in the selection of the optimum size and design of blower.

### B 9.2 Systems

Various rotary and hot wire anemometers are available for measuring flow rate, and in addition dynamic and static head can be measured by pitot tube.

Measurement of power in the air flow requires a knowledge of the velocity, mass flow and static head. A pitot static head measures total head and static head, and a differential pressure gage sensing the difference between these pressures provides the dynamic or velocity head. The differential pressure gage is usually of the order of  $\pm 1/2$  psi. See Figure B-32.

The velocity head is used as a reference pressure for that particular section of the duct and average velocity is obtained from the duct calibration curve. To avoid the highly sensitive differential gage, a combination of rotary anemometer with a frequency output and static head pick up and pressure transducer may be used.

Static and differential pressures will tend to fluctuate violently in rough water and mechanical damping in the form of an adjustable needle valve orifice on the pitot side of a damping chamber is desirable. In this case protection of the sensitive pressure transducers from peak pressures, and a settling chamber (see Figure 32A) to take out water droplets make the mechanical damping system preferable to putting all damping in the electrical system.

Setting up of pitot static tubes has been found to be a problem due to reversal of flow in a severely pounding ARCK. A small size of unit is not recommended.

### B 9.3 Calibration

The duct section is calibrated by carrying out a transverse with a pitot static tube so that a surface plot of differential pressure is made for a set of blower speeds. This is carried out with the vehicle on blocks and pressures are recorded on a sensitive inclined water gage. Increased sensitivity may be obtained with a liquid of known low specific gravity.

Operating static pressures are preferably simulated by restricting the duct outlet.

One position on the section is chosen for the pitot static tube to be used on the tests and a calibration curve of average duct velocity drawn up against the measured velocity head at the chosen position.

The same system applies to a rotary sensor.

The static head pressure transducer is calibrated by a water gage.



AIR DIFFERENTIAL PRESSURE  
TRANSDUCER AND SETTLING CHAMBERS

FIGURE B-32

## B 10.0 WEIGHT AND CENTER OF GRAVITY

### B 10.1 Requirements

The gross weight and center of gravity of the vehicle are important both to the designer and the user. Vehicle performance is measured for a set of gross weight and center of gravity positions, the latter usually being limited by the available testing time to longitudinal movements only. A preferred position for the c.g. is thus found, as well as the disadvantages of mis-loading.

Similarly the effect of gross weight on power and motion performance shows the penalties incurred through exceeding design weight as well as vehicle behavior in the unloaded condition.

### B 10.2 Systems

Gross weight can be measured on truck scales, on aircraft scales individually located under each wheel (which also provides longitudinal and lateral center of gravity position), by a single crane, by two cranes, or by a combination of one crane and scales.

It usually is convenient to obtain gross weight and c.g. simultaneously. One of the simplest methods is to obtain two cranes and lift at or near bow and stern simultaneously. If the lifting points are about evenly placed from the approximately known c.g. position, the cranes do not each have to be rated for the full weight of the vehicle.

With one dynamometer, two lifts are needed with the dynamometer first in one leg of the lift and then in the other leg. One crane head is moved so that the lift cables are parallel (by eye) each time the vehicle is lifted.

The gross weight is taken by adding the weight found from each lift, and the longitudinal center of gravity is found by taking moments about any convenient transverse axis from which the horizontal distance to each crane lift line is known.

A single crane may be used in conjunction with a standard sling and plumb bob suspended from the point of support at the hook. The vehicle longitudinal c.g. position may be found by adding known weights at known locations to level it, or by purposefully slinging the vehicle at an angle with an uneven sling. The latter method will also provide the height of center of gravity as well as the longitudinal position, as follows. After scribing a line on the side of the vehicle parallel to the plumb line and on a vertical transverse section at right angles to the vehicle center line, the sling is reversed and a new line scribed. The point of intersection gives the height and longitudinal position of the c.g. See Figure B-33.

### B 10.3 Calibration

The load cells used are calibrated on a tensile testing machine in any convenient mechanical testing laboratory. The calibration record of the test machine should be checked to see that it is less than one year old. A calibration table will be prepared for and used as the load cell calibration curve.



## B 11.0 WAVE HEIGHT MEASUREMENT

### B 11.1 Requirements

It is required to record, analyse and express wave height and period on a statistical basis. The basis chosen for expressing wave height is:

- a) The arithmetic mean of wave heights (trough to crest),
- b) The average of the one third highest (which is termed the "significant wave height").

A record of waves numbering 200 will give a 90% probability of accuracy and preferably at least 200 waves should be recorded. However, since the period can vary from one to nine seconds the duration of the record will then vary from about three minutes to about twenty-five minutes. Clearly the latter duration is excessive for photography and a compromise is necessary. Every effort should be made to record photographically for a period of not less than three minutes but preferably six to ten minutes. While the accuracy in expressing sea state will degrade considerably with so small a statistical aperture, the data so obtained will be acceptable for expressing general vehicle motion; the extremes of sea wave height will however be lost.

### B 11.2 Systems

Wave measurement is time consuming and difficult. Several methods have been tried with varying degrees of success including; a wave staff on a bottom mounted fishing tower protruding through the surface and photography; a wave staff secured to a moored sub surface buoy, resistance being recorded as a wave sweeps through metal resistance wires affixed to the staff; the David Taylor Model Basin "Splash Nik" which transmits the axial acceleration of a float to a receiver/recorder; a bottom mounted wave staff that is marked and photographed. The David Taylor Model Basin and wave staff and photography methods were the most dependable. However the David Taylor Model Basin system requires a launch to position and monitor the buoy and an engineer to conduct the tests and process the record to derive wave height. These requirements are usually beyond U. S. Marine Corps resources and efforts are being made to use the wave staff and photography. A description of one of these systems which has yet to be tried out is contained in Appendix C.

## APPENDIX C

## WATER PERFORMANCE TEST PLANS

## 1.0 GENERAL

The planning papers used for the LVW tests at the West Coast during the spring of 1966 are provided in this Appendix as examples of test planning.

## 2.0 TEST PLAN

The first section is the Test Instruction Sheets, preceeded by the Test Sheet Index. Sets of these sheets are issued for the use of the Project Officer, the instrumentation engineer, chase boat crew and shore party. The appropriate sheets are designated at each pre-run briefing and serve:

- (a) To correlate activities of all test personnel;
- (b) To instruct driver of test vehicle;
- (c) To record notes on the test conditions, occurrences and trace record numbers for use in the analysis.

## 3.0 TEST PROGRAM NOTES

The notes give brief information on parameters being measured, evaluations, time limitations, and climatological data to provide a background for all test personnel.

The test schedule is then given, showing first and second priorities.

Lastly a set of operational notes provides information on the running of the tests, with brief statements on pre-run briefing, chase boat, standard conditions, instruction sheets and repeatability of data.

## 4.0 TEST ORGANIZATION

The last section covers the dispositions and handling of the test vehicle and chase boat during work on each of the test sheets, beginning with a daily starting time table.



## C 5.0 TEST SHEET INDEX

Sheet No.

C 5.1	High Speed Series
C 5.2	Low Speed Series
C 5.3	Transition and Acceleration
C 5.4	Heading
C 5.5	Resonant Operation
C 5.6	Forward C.G.
C 5.7	Mid C.G.
C 5.8	Aft C.G. (A)
C 5.9	Aft C.G. (B)
C 5.10	Standard G. W.
C 5.11	Low G. W.
C 5.12	High G. W.
C 5.13	Control: Low Speed Range
C 5.14	Control: High Speed Range
C 5.15	Control: Maneuver - Rudder Angle
C 5.16	Control: Cruise - Rudder Angle
C 5.17	Control: Wheel Steering and Combinations
C 5.18	Speed Calibration: High Range
C 5.19	Speed Calibration: Low Range
C 5.20	Thrust Calibration

Test Instruction Sheet

No. 5.1

VEHICLE: LVW-X2			DATE:		
SHEET NO: 1      SEA STATE:			LOCATION: West Coast Branch		
MISSION: High Speed Series			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed			Personnel		
Heading/Rudder	45° on bow		Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	20 knots steady. Hold 4 minutes.	Run:		
2	22.5 knots steady. Hold 4 minutes.	Run:		
3	25 knots steady. Hold 4 minutes.	Run:		
4	27.5 knots steady. Hold 3 minutes.	Run:		
5	Maximum speed. Hold 3 minutes.	Run:		
6		Run:		
7		Run:		
8		Run:		

# Test Instruction Sheet

No. 5.2

2-4

VEHICLE: LVW-X2			DATE:		
SHEET NO: 2      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Low Speed Series			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	45° on bow		Personnel		
Heading/Rudder	236 in.		Fuel		
Center of Gravity			Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	5 knots steady. Hold 4 minutes.	Run:		
2	7.5 knots steady. Hold 4 minutes.	Run:		
3	10 knots steady. Hold 4 minutes.	Run:		
4	12.5 knots steady. Hold 4 minutes.	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

## Run Instruction Sheet

No. 5.3

VEHICLE: LVW-X2			DATE:		
SHEET NO: 3      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Transition and Acceleration			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed			Personnel		
Heading/Rudder	45° on bow		Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		
NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES	
1	Accelerate zero to maximum. Throttle maximum acceptable settings.	Run:			
2	Accelerate through transition. Find minimum throttle setting.	Run:			
3	Accelerate through transition.	Run:			
4	Accelerate through transition.	Run:			
5	Accelerate through transition.	Run:			
6	Accelerate through transition.	Run:			
7	Accelerate through transition.	Run:			
8		Run:			

## Test Instruction Sheet

No. 544

VEHICLE: LVW-X2			DATE:		
SHEET NO: 4      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Heading			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder			Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Proceed into seas. (Referred to as 0° heading.) Hold 3 minutes.	Run:		
2	Proceed 45° to sea. Hold 3 minutes.	Run:		
3	Proceed 90° to sea. Hold 3 minutes.	Run:		
4	Proceed 135° to sea. Hold 4 minutes.	Run:		
5	Proceed stern to sea. Hold 5 minutes.	Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.5

VEHICLE: LVW-X2			DATE:		
SHEET NO: 5      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Resonant Operation			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed			Personnel		
Heading/Rudder			Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Run head to sea. Vary speed to obtain resonant pitching. Hold 3 minutes.	Run:		
2	Vary heading and speed to obtain resonant rolling. Hold 3 minutes.	Run:		
3		Run:		
4		Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.6

VEHICLE: LVW-X2			DATE:		
SHEET NO: 6		SEA STATE:	LOCATION: West Coast Branch		
MISSION: Forward C.G.			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder	45° to sea		Fuel		
Center of Gravity	232 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Accelerate to maximum speed.	Run:		
2	Hold 25 knots 4 minutes.	Run:		
3	Accelerate through transition to maximum speed.	Run:		
4	Hold 25 knots 4 minutes.	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.7

VEHICLE: LVW-X2			DATE:		
SHEET NO: 7		SEA STATE:	LOCATION: West Coast Branch		
MISSION: Standard C.G.			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder	45° to sea		Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Accelerate to maximum speed.	Run:		
2	Hold 25 knots 4 minutes.	Run:		
3	Accelerate through transition to maximum speed.	Run:		
4	Hold 25 knots 4 minutes.	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		



Test Instruction Sheet

No. 5.8

VEHICLE: LVW-X2			DATE:		
SHEET NO: 8      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Aft C.G. (A)			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder	45° to sea		Fuel		
Center of Gravity	240 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Accelerate to maximum speed.	Run:		
2	Hold 25 knots 4 minutes.	Run:		
3	Accelerate through transition to maximum speed.	Run:		
4	Hold 25 knots 4 minutes.	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.9

VEHICLE: LVW-X2			DATE:		
SHEET NO: 9      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Aft C.G. (B)			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder	45° to sea		Fuel		
Center of Gravity	244 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Accelerate to maximum speed.	Run:		
2	Hold 25 knots 4 minutes.	Run:		
3	Accelerate through transition to maximum speed.	Run:		
4	Hold 25 knots 4 minutes	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.10

VEHICLE: LVW-X2			DATE:		
SHEET NO: 10      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Standard Gross Weight			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder	45° to sea		Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Accelerate to maximum speed.	Run:		
2	Hold 25 knots 4 minutes.	Run:		
3	Accelerate through transition to maximum speed.	Run:		
4	Hold 25 knots 4 minutes.	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

## Run Instruction Sheet

No. 5.11

VEHICLE: LVW-X2			DATE:		
SHEET NO: 11      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Low Gross Weight			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder	45° to sea		Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	38,500 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Accelerate to maximum speed.	Run:		
2	Hold 25 knots 4 minutes.	Run:		
3	Accelerate through transition to maximum speed.	Run:		
4	Hold 25 knots 4 minutes.	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.12

VEHICLE: LVW-X2			DATE:		
SHEET NO: 12      SEA STATE:			LOCATION: West Coast Branch		
MISSION: High Gross Weight			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder	45° to sea		Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	41,500 lbs.		Other		
NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES	
1	Accelerate to maximum speed.	Run:			
2	Hold 25 knots 4 minutes.	Run:			
3	Accelerate through transition to maximum speed.	Run:			
4	Hold 25 knots 4 minutes.	Run:			
5		Run:			
6		Run:			
7		Run:			
8		Run:			

Test Instruction Sheet

No. 5.13

VEHICLE: LVW-X2 (Wheels Up)			DATE:		
SHEET NO: 13      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Control: Low Speed Range			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	Full Port 236 in. 40,000 lbs.		Personnel		
Heading/Rudder			Fuel		
Center of Gravity			Ballast		
Gross Weight			Other		
NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES	
1	From straight and steady on 5 knots, make one full turn at this throttle.	Run:			
2	Increase throttle to steady on 5 knots. Make one full turn.	Run:			
3	Straight and steady on 7.5 knots. Make one full turn at this throttle.	Run:			
4	Increase to steady on 7.5 knots. Make one full turn.	Run:			
5	Straight and steady on 10 knots. Make one full turn at this throttle.	Run:			
6	Increase throttle to steady on 10 knots. Make one full turn.	Run:			
7		Run:			
8		Run:			

## Test Instruction Sheet

No. 5.14

VEHICLE: LVW-X2 (Wheels Up)			DATE:		
SHEET NO: 14      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Control: High Speed Series			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed			Personnel		
Heading/Rudder	Full Port		Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	From straight and steady on 20 knots, make one full turn, increasing throttle to hold 20 knots.	Run:		
2	Straight and steady on 25 knots. Make one full turn increasing throttle to hold 25 knots.	Run:		
3	Straight and steady on maximum speed. Make one full turn.	Run:		
4		Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.15

VEHICLE: LVW-X2 (Wheels Up)			DATE:		
SHEET NO: 15      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Control: Maneuver Rudder			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	5 knots		Personnel		
Heading/Rudder			Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Straight and steady on 5 knots. Apply 10° rudder. Make one full turn.	Run:		
2	Straight and steady on 5 knots. Apply 20° rudder. Make one full turn.	Run:		
3	Straight and steady on 5 knots. Apply full rudder. Make one full turn.	Run:		
4		Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		



# Test Instruction Sheet

C-18

No. 5.16

VEHICLE: LVW-X2 (Wheels Up)			DATE:		
SHEET NO: 16 SEA STATE:			LOCATION: West Coast Branch		
MISSION: Control: Cruise - Rudder			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	25 knots		Personnel		
Heading/Rudder			Fuel		
Center of Gravity	236 in.		Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Straight and steady on 25 knots. Apply 10° rudder. Make one full turn. Hold speed.	Run:		
2	Straight and steady on 25 knots. Apply 20° rudder. Make one full turn. Hold speed.	Run:		
3	Straight and steady on 25 knots. Apply maximum rudder. Hold speed.	Run:		
4		Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

Test Instruction Sheet

No. 5.17

VEHICLE: LVW-X2 (Wheels Down)			DATE:		
SHEET NO: 17      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Control: Wheel Steering			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed Heading/Rudder Center of Gravity Gross Weight	236 in. 40,000 lbs.		Personnel Fuel Ballast Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Straight and steady on 5 knots. Apply full left on wheels only. Make one full turn.	Run:		
2	Straight and steady on 10 knots. Apply full left on wheels only. Make one full turn.	Run:		
3	Straight and steady on 5 knots. Apply full left on wheels and rudder. Make one full turn.	Run:		
4	Straight and steady on 10 knots. Apply full left on wheels and rudder. Make one full turn.	Run:		
5		Run:		
6		Run:		
7		Run:		
8		Run:		

## Test Instruction Sheet

No. 5.18

VEHICLE: LVW-X2 (Wheels Up)			DATE:		
SHEET NO: 18      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Speed Calibration: Low Range			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	Transits		Personnel		
Heading/Rudder	236 in.		Fuel		
Center of Gravity			Ballast		
Gross Weight	40,000 lbs.		Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Hold steady on 5 knots past transits. North	Run:		
2	Hold steady on 5 knots past transits. South	Run:		
3	Hold steady on 7.5 knots past transits. North	Run:		
4	Hold steady on 7.5 knots past transits. South	Run:		
5	Hold steady on 10 knots past transits. North	Run:		
6	Hold steady on 10 knots past transits. South	Run:		
7		Run:		
8		Run:		

## Test Instruction Sheet

No. 5.19

VEHICLE: LVW-X2 (Wheels Up)			DATE:		
SHEET NO: 19      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Speed Calibration: High Range			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed	Transits		Personnel		
Heading/Rudder	236 in.		Fuel		
Center of Gravity	40,000 lbs.		Ballast		
Gross Weight			Other		

NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES
1	Hold steady on 20 knots past transits. North.	Run:		
2	Hold steady on 20 knots past transits. South.	Run:		
3	Hold steady on 25 knots past transits. North.	Run:		
4	Hold steady on 25 knots past transits. South	Run:		
5	Hold steady on 30 knots past transits. North.	Run:		
6	Hold steady on 30 knots past transits. South.	Run:		
7	Hold steady on maximum speed past transits. North.	Run:		
8	Hold steady on maximum speed past transits. South.	Run:		

Test Instruction Sheet

No. 5.20

VEHICLE: LVW-X2			DATE:		
SHEET NO: 20      SEA STATE:			LOCATION: West Coast Branch		
MISSION: Thrust Calibration			OPERATOR:		
TEST CONDITIONS:	REQUIRED	USED	LOADING	WT.	C.G.
Speed Heading/Rudder Center of Gravity Gross Weight			Personnel Fuel Ballast Other		
NO.	RUN INSTRUCTION	CEC	TRACE NO.	NOTES	
1	Rig for Bollard calibration. N <sub>2</sub> 40%	Run:			
2	N <sub>2</sub> 50%	Run:			
3	N <sub>2</sub> 60%	Run:			
4	N <sub>2</sub> 70%	Run:			
5	N <sub>2</sub> 80%	Run:			
6	N <sub>2</sub> 90%	Run:			
7	N <sub>2</sub> Maximum.	Run:			
8		Run:			

## C 6.0 TEST PROGRAM NOTES

C 6.1 Measured Parameters

The program employs a uniform system applicable to all amphibian vehicle types in order to comply with the need for compatible data. The measured parameters have been reduced to water speed and thrust for effective power, and torque and engine r.p.m. for shaft power, from which the propulsion efficiency is derived. Motion data are obtained from one crew, one cargo compartment, and one stern vertical accelerometer, and one roll and pitch gyro. Sea state is to be recorded using a staff and movie camera operated from the chase boat. If time permits, control data will be obtained.

C 6.2 Evaluation

The test program evaluates power and motion performance with respect to speed, sea state, loading and heading only. Loading is determined by a) gross weight of vehicle, b) center of gravity of loaded vehicle. Control characteristics, if measured, will be evaluated in terms of speed and rudder angle.

Standard values are assigned to loading, speed and heading which are to be used on the vehicle during the tests as closely as possible unless otherwise noted. Uncorrected deviations such as bilge water, crew numbers, fuel, are to be noted in the test run sheets.

C 6.3 Time Limitation

In view of the necessarily brief time available for testing, time of run for obtaining a sufficient aperture for analysis of motion data has been cut to a nominal 50 wave impacts per test run out of the 200 input requirement. Validity of results consequently must be down graded, but expected operational hours of the vehicle within the test time period was a factor in this decision.

C 6.4 Climatological Atlas

Under the conditions experienced at Little Creek during the November and December tests on the ARCK, testing was carried out during ten days out of approximately 40 working days, an average of 25%. Due to past experience with the LVW and assuming approximately the same performance for the instrumentation, an estimate of 20% utilization is made under the favorable maintenance conditions at the West Coast Branch, or five days out of 25 working days between 28 February and 1 April. The Climatological Atlas of the Bureau of Commerce shows for offshore California, surface winds predominately North and Northwest for 20% of the time each and South for

about 10% of the time. The same data shows wind strengths to be 10 - 20 knots for about 10% of the time and 20 - 30 knots for about 5% of the time for the North and Northwest winds.

Seas ≡ five feet have been observed for 20% of the time and seas ≡≡ eight feet for 10% of the time and ≡≡≡ twelve feet for 2% of the time.

There are insufficient data to correlate the offshore observations with inshore sea state in the Atlas. If seas ≡ five feet offshore correlate with sea state 2 inshore and seas ≡≡ eight feet offshore with sea state 3 inshore, we can expect sea state 2 for 10% and sea state 3 for 10% of the time.

## C 7.0 TEST SCHEDULE

The tests are arranged in order of importance within each sea state. Priority 2 tests would be restricted until all Priority 1 runs have been completed in order to conserve running time of the vehicle. The schedule in the Priority Table, page C-34, provides a basic method for getting the maximum results in the event of premature curtailment of the testing.

If and when more time becomes available in each sea state, remaining test sheets may be completed. Smooth sea conditions will probably not be available but a low swell (say two feet significance) of long period (say twelve seconds up) should be a reasonable approximation to "calm" with all runs made parallel to crests. A superimposed sea more than six inches may affect results.

## C 8.0 TEST OPERATIONAL NOTES

### C 8.1 Briefing

Once the operational readiness of all vehicle and instrumentation systems has been established, and firefighting, life saving, communication and shipboard equipment has been checked, a pre-run briefing will be held by the Project Officer or designee. This will be attended by the LVW operating crew, the instrumentation crew, chase boat crew and implicated West Coast Branch personnel.

The next run instruction sheet or sheets will be designated and dispositions of the LVW and chase boat during the runs will be arranged. Readiness will be checked, the latest weather and sea forecasts will be given out and the go ahead or otherwise received from O.I.C., West Coast Branch or his representative.

### C 8.2 Chase Boat

The chase boat, in addition to its duties of ensuring the safety of the operation, will be required to support the photographic records of the tests. This means, that in general, the chase boat will have to stay close to the LVW for as long as possible during the runs, and the sheet

and run number will be transmitted to the chase boat for setting on the indicator board. This appears to be consistent with the safety duties.

Time will have to be allocated for shooting at least 50 feet of film of the wave staff in any morning's or afternoon's operations.

### C 8.3 Standard Conditions

Standard values are assigned to loading, speed and heading which are to be used on the vehicle during the tests as closely as possible unless otherwise requested in the run sheets. Uncorrected deviations such as bilge water, crew numbers, fuel, are to be noted in the test run sheets. Loading is determined by (a) gross weight of vehicle, (b) center of gravity of loaded vehicle.

### C 8.4 Instruction Sheets

Sea state has not been specified on the run instruction sheets. The vehicle will be tested in as wide a variety of sea conditions as present themselves, and estimated sea conditions noted on the sheets. These estimates will later be upgraded from camera records.

### C 8.5 Repeatability

Some repetition has been included in the run instructions, but sheets 1, 2, and 4 are intended to be repeated in full at least once in the same sea conditions.

## C 9.0 TEST ORGANIZATION

### C 9.1 Starting Time Table

- C 9.1.1      07.30: Switch on instrumentation for warm up.
- C 9.1.2      07.35: Pre-run briefing begins. Select next priority test sheet after receiving information on sea conditions. Check readiness of vehicle, chase boat, instrumentation, all personnel. Brief all personnel on test sheet, disposition of chase boat and refuelling plan. Receive go ahead from West Coast Branch Officer in Charge.
- C 9.1.3      07.55: Briefing ends.
- C 9.1.4      08.00: Chase boat leaves for assigned test area, sets up wave staff and takes three minutes of film.
- C 9.1.5      08.00: Set zeros, check R cals.
- C 9.1.6      08.15: Start up LVW; check all systems.
- C 9.1.7      08.30: LVW leaves for test area.



C 9.2 Standard Sheet Procedure. Runs 45° To Sea

- C 9.2.1 On arrival at test area, LVW signals sheet number to chase boat.
- C 9.2.2 LVW stops to reset zeros, show R calcs and check drift.
- C 9.2.3 LVW and chase boat starting positions are arranged so that they are both outside the six fathom line with the chase boat one mile ahead on a course 45° to sea on port bow. See Figure C 9-1.
- C 9.2.4 At start of run, chase boat proceeds at maximum speed on same course as LVW.
- C 9.2.5 As LVW approaches, chase boat slows if necessary to be more stable for photography.
- C 9.2.6 LVW signals run number to chase boat to correlate photography.
- C 9.2.7 LVW passes within 50 feet of chase boat and continues to a position one mile beyond.
- C 9.2.8 LVW stops to show zero drift, R calcs and reset zeros.
- C 9.2.9 Chase boat continues at full speed on same course until LVW stops.
- C 9.2.10 Both chase boat and LVW return to original positions in displacement mode for further runs.
- C 9.2.11 LVW stops to show zero drift, R calcs and reset zeros before starting each course.

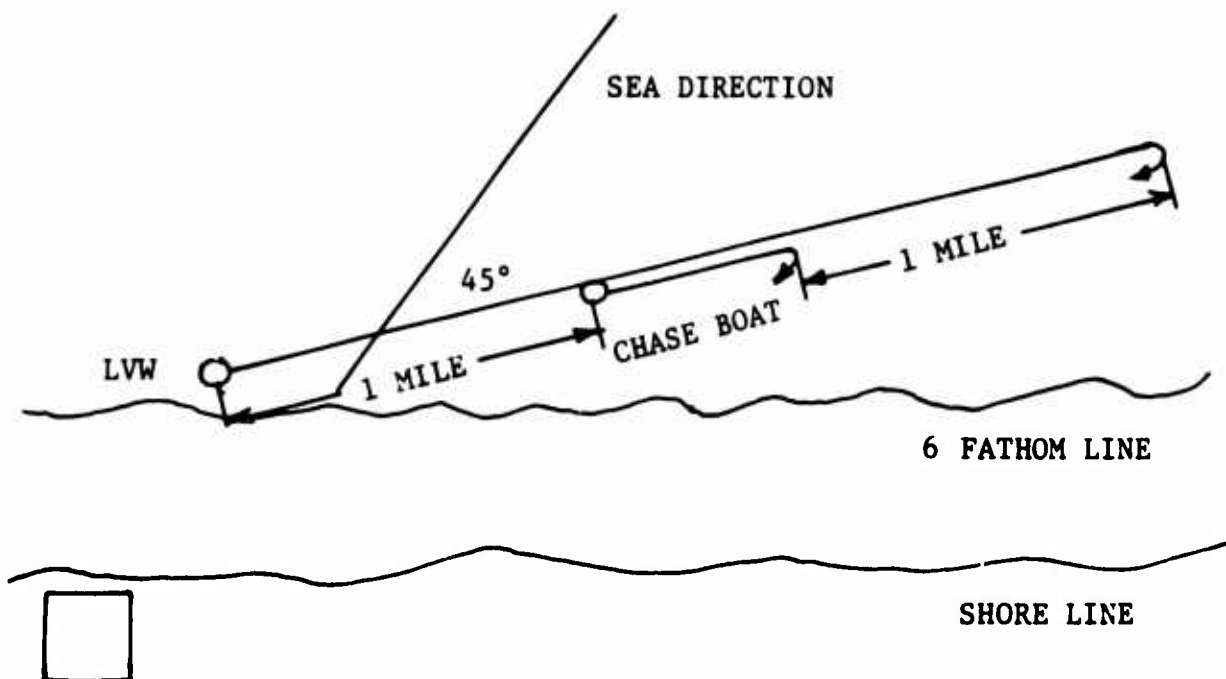


FIGURE C-9.1

### C 9.3 Heading Sheets

- C 9.3.1 On arrival at the test area, LVW signals the sheet number to chase boat.
- C 9.3.2 LVW stops to reset zeros, show R cals and check drift.
- C 9.3.3 LVW and chase boat starting positions are arranged so that they are both outside the six fathom line with the chase boat one mile ahead on a course  $45^\circ$  to sea. See Figure C 9-2.
- C 9.3.4 The LVW accelerates to standard speed and proceeds for 1 1/2 minutes on successive runs at  $0^\circ$ ,  $45^\circ$  and  $90^\circ$  to sea. See Figure C 9-2.
- C 9.3.5 The chase boat proceeds at  $0^\circ$  to sea at full speed and changes course in consort with the LVW.
- C 9.3.6 On completion of the  $90^\circ$  run, the LVW moves at displacement mode to a position one mile outside the six fathom line and completes the  $135^\circ$  to sea run for 1 1/2 minutes as in Figure C 9-3.
- C 9.3.7 The LVW returns to a position one mile outside the six fathom line and completes the run  $180^\circ$  to sea for 1 1/2 minutes.
- C 9.3.8 During the  $135^\circ$  and  $180^\circ$  runs of the LVW, the chase boat returns to its starting position at a speed which permits passing close to the LVW for photography. See Figure C 9-3.
- C 9.3.9 Repeat C 9.3.2 to C 9.3.8 to obtain 3 minutes running time.

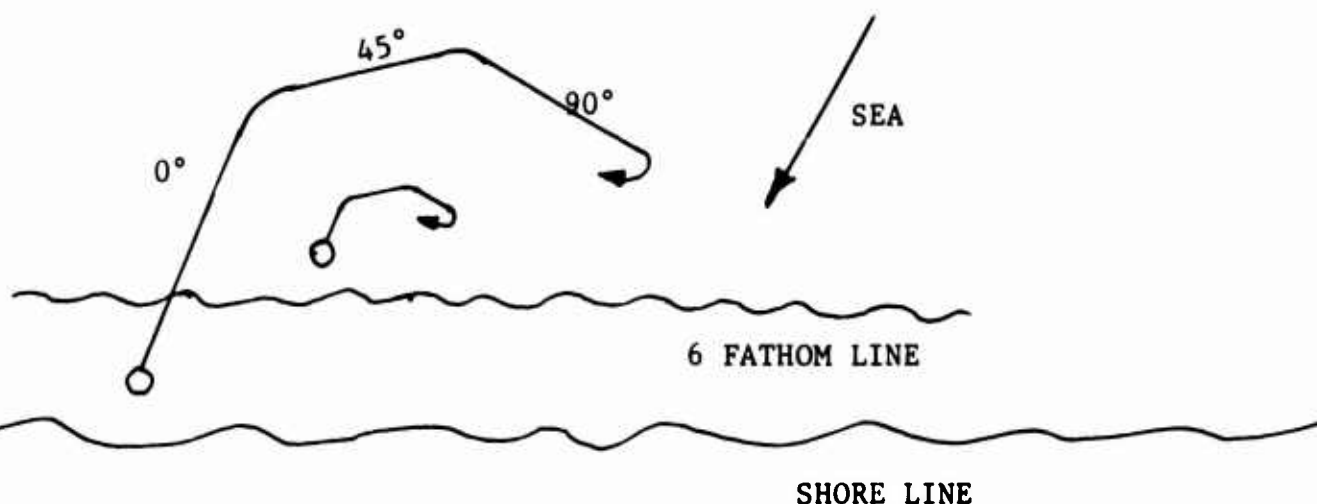


FIGURE C-9.2

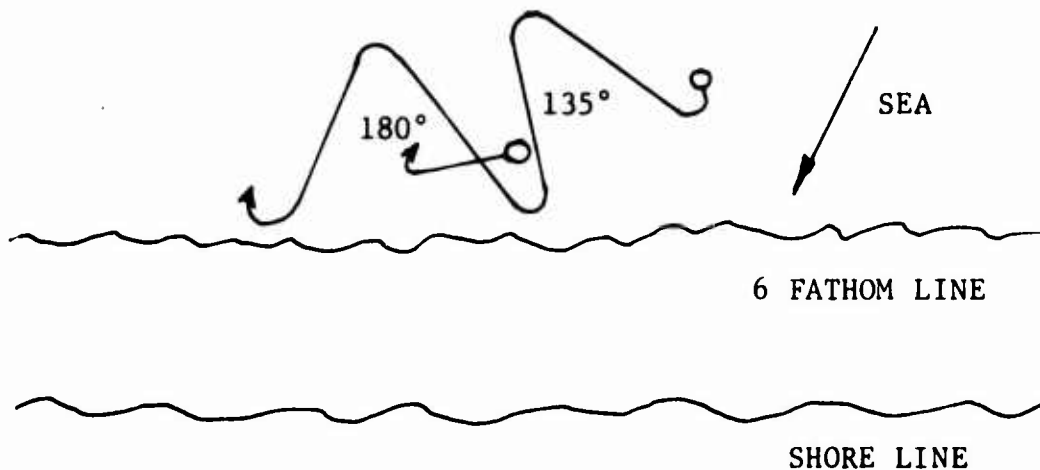


FIGURE C-9.3

#### C 9.4 Speed Calibration Sheets

- C 9.4.1 The LVW stops to reset zero on the speed channel and show R calcs.
- C 9.4.2 The LVW starting station is chosen so that sufficient room is available to steady on the first speed before crossing the first transit.
- C 9.4.3 The LVW course is set at right angles to the transit lines and as close to the six fathom line as permits the transit markers to be seen clearly.
- C 9.4.4 The chase boat's station is on the 1/2 mile transit and approximately the same distance offshore as the LVW.
- C 9.4.5 Below planing speed, the LVW speed is timed on 1/4 mile courses by stop watch, one run in each direction.
- C 9.4.6 Above planing speed, the LVW speeds are timed on 1/2 mile courses, one run in each direction.

#### C 9.5 Pitch and Roll Calibration

- C 9.5.1 Pitch calibration is carried out during routine testing by photography under any test conditions.
- C 9.5.2 When the LVW is passing the chase boat at close range to seaward during a run, the command is given to "check pitch" over the radio.
- C 9.5.3 On the command, the photographer starts the camera and continues photography as usual.

- C 9.5.4 On the command, the cabin operator momentarily stops the recorder and switches on again and carries on as usual. The trace number is noted as "check pitch".
- C 9.5.5 To identify the film, the camera operator preceeds the "check pitch" sequence with two or three frames of part of chase boat, hand, etc.
- C 9.5.6 To check roll, when the LVW and chase boat are about to return to dock after a test sequence, the LVW stops in an attitude parallel to wave crests, bow to seaward.
- C 9.5.7 The chase boat maneuvers to line up with the stern of the LVW at close range, and maintains station.
- C 9.5.8 On the command "check roll", the camera is started and three complete rolls filmed.
- C 9.5.9 On the command "check roll", the cabin operator starts the recorder and stops after three complete rolls. The record number is identified as "check roll".

#### C 9.6 Control Sheets

- C 9.6.1 The LVW and chase boat proceed to a point just outside the six fathom line.
- C 9.6.2 The chase boat maneuvers to keep clear of the LVW during control runs but close enough to permit photography.

## C 10.0 HIGH SURF TEST PLAN

C 10.1 Vehicle and Instrumentation Preparation

- C 10.1.1 Install six (6) range poles; premounted brackets are located on the Plimsoll line (each side) at the stern, amidship and at the bow.
  - a) Poles will extend approximately 6 feet above the vehicle.
  - b) Poles will be striped in one foot increments using the vehicle Plimsoll line as a base.
- C 10.1.2 Install load weights under the direction of the West Coast Branch Engineering Department.
- C 10.1.3 Install instrumentation under the direction of the West Coast Branch Engineering Department. The instrumentation package will consist of a pressure transducer for recording vehicle atmosphere pressure changes, roll and pitch gyro, carbon monoxide detector and the appropriate signal conditioning, recording and timing equipment
- C 10.1.4 Pressure heads and cables will be installed in about 30 feet of water and connected to a recorder/timer for measuring surf height and period.
- C 10.1.5 Sixteen mm movie and still photography will be provided and a tower will be erected to facilitate the former.
- C 10.1.6 Inspect and service the vehicle in accordance with applicable Technical Manual. Special attention must be directed toward those systems or components peculiar to the test vehicle:
  - a) Aspiration system,
  - b) Fuel system,
  - c) The diesel engine and its auxiliaries.

C 10.2 Preliminary Checkout

- C 10.2.1 Operate the test vehicle over the beach and in a low surf. Low surf is defined as being less than 5 feet high.
- C 10.2.2 Several cycles will be required in order to check out the following:
  - a) Vehicle operation,
  - b) Load weight security,
  - c) Instrumentation,
  - d) Communications,
  - e) Test coordination.

### C 10.3 High Surf Operations

C 10.3.1 Recheck the following items prior to entering the high surf:

- a) Test vehicle controls,
- b) Instrumentation,
- c) Load weight security,
- d) Communications.

C 10.3.2 Complete 6 round trips through the high surf zone when the significant surf series (as defined by Unit SOP) is within one and one half (1 1/2) feet of 10 feet.

- a) Using the form shown in Figure C-1 , record the following data during the above runs:

Vehicle atmospheric pressure change  
CO concentration  
Roll  
Pitch  
Time for transit

C 10.3.3 Repeat the above runs as necessary until the following criteria are met:

- a) Six (6) plunging type breakers are encountered on runs toward the beach;
- b) These breakers must be not less than nine (9) feet high;
- c) A minimum of three (3) of these breakers must break under or against the stern of the vehicle.

C 10.3.4 Repeat the above runs in both the loaded and unloaded conditions.

### C 10.4 Administrative Instructions

C 10.4.1 As soon as possible after each run, report the following data to the Officer in Charge, Surf Test Department.

- a) Maximum vehicle atmospheric pressure change,
- b) Maximum CO concentration.

C 10.4.2 Prepare a weekly progress report for the Officer in Charge, West Coast Branch. This report will cover the week's operation and contain information pertaining to the following:

- a) Operational time;
- b) Data collected;
- c) Maximum vehicle atmospheric pressure change, CO concentration and motions encountered;
- d) Significant problems.

C 10.4.3 Prepare an engineering report at the completion of the test to be included in the final report.

## LVW TESTS AT WEST COAST BRANCH

## PRIORITY TABLE

SEA STATE	FIRST PRIORITY		SECOND PRIORITY	
	SHEET	MISSION	SHEET	MISSION
3	3	Acceleration	4	Heading
	1	High Speed Series	2	Low Speed Series
2	3	Acceleration	1	High Speed Series
	4	Heading	5	Resonant Op.
	2	Low Speed Series		
1	3	Acceleration	10,11,12	Gross Weight
	6,7,8,9	C. G. Series	13	Control, Low Speed
	1,2	Speed Series	15	Control, Rudder
Calm *	3	Acceleration	6,7,8,9	C. G.
	1,2	Speed Series	10,11,12	Gross Weight
	18,19	Speed Cals.		
Harbour	20	Thrust Cal.		

\* See Section C 7.0



## HIGH SURF DATA SHEET

TEST VEHICLE \_\_\_\_\_ SITE \_\_\_\_\_

DATE \_\_\_\_\_ TIME \_\_\_\_\_

SURF RUN NO. \_\_\_\_\_ LOAD \_\_\_\_\_

		TO SEA	FROM SEA
Significant Wave Height			
Breaker Type			
Average Period			
Littoral Current	Direction		
	Velocity		
Wind	Direction		
	Velocity		
Maximum Change in Atmospheric Pressure			
Maximum Carbon Monoxide Concentration			
Maximum Roll			
Maximum Pitch			
Transit Time			
REMARKS (to include breaker action relative to surfing vehicle):			

Figure C -1

## C 11.0 WAVE STAFF

C 11.1 General Description

The wave staff is designed to rest on the sea bottom in 30 feet of water and indicate wave height against a scale marked in alternate black and white bands each one foot long. The wave height is recorded by a movie camera. The staff is designed to resist moderate currents of up to 1/2 knot and remain sufficiently steady to permit rapid analysis of wave height without wave to wave corrections for angle of heel of the staff as recorded by the camera.

The staff consists of three twelve foot lengths of 1 1/4 inch outer diameter alloy tube joined end to end with releasable joints. The staff is weighted at its lower end and a righting moment is provided by floats retained near the middle of the staff. A handling line is lashed to the weighted end and the other end of the line is attached to a light mooring float.

C 11.2 Adjustments

Several adjustments are available in the staff. The first is righting moment. The staff is provided with ring shaped weights made of lead of which a desired number may be fitted at the lower end of the staff. It is also fitted with a set of cylindrical plastic floats of which any desired number may be placed at any position on the staff.

The upper two sections of the staff are sealed to aid flotation and the lower section is vented to ensure flooding.

The number of lead weights and floats is adjusted so that when the floats are sufficiently low on the staff to avoid too much sway during the passage of waves, sufficient righting moment is available to resist the prevailing current without more than about 10° average heel. The righting moment should otherwise be minimised to keep the staff as light as possible for ease of handling. Additional excess weight is fitted to ensure the staff rests firmly on the bottom.

In cases of persistent dragging of the staff, a small anchor on a short line of about 5 feet is made fast to the lower end of the staff.

The weights are varied by removing the two lower bolts and locknuts, sliding out the weight tube and changing the weights.

The floats are adjusted by loosening the hose clamps retaining the float retaining washers, and sliding the retainer off the end of the staff or to a new location on the tube.

After fitting the center section, which will probably have most of the floats on it, the two joined sections are lowered vertically until the upper end is again in position for joining.

The upper section is then raised in position and a joint made as before, before lowering the complete staff to the bottom.

The buoy and the rest of the handling line is then cast overboard.

The reverse procedure is used in picking up the staff.

C 11.3 Operation

The staff is designed to be tended by the chase boat, which takes at least three minutes of film during each day's testing. If no significant change in sea state takes place, the chase boat takes one and a half minutes before the start of testing and one and one half minutes after testing finishes for the day. If a change occurs, the chase boat takes additional film at the discretion of the Project Officer to relate sea state to the tests.

Two methods of handling the staff are available. The preferred method is the simpler and demands the lesser skill in seamanship, but may impose loads on the staff in sea state 3 which may require its frequent repair.

In this the staff is fully assembled and placed in a convenient location in the boat basin out of the way of basin operations. Before a test, the chase boat picks up the mooring buoy and hands in the line raising the weighted end of the staff (and small anchor if fitted) to the surface. The staff should then lie at the surface of the water. In this attitude the staff is towed to the test area and released when the depth sounder records a steady five fathoms.

In harbor the handling line is kept short to aid in maneuvering, and a rope or sponge fender may be attached to the weighted end of the staff to avoid any damage to topsides. The fender should not have buoyancy.

Once out of the harbor, the handling line may be paid out and the staff towed at short distance behind so that motion in the seaway will not provide the risk of contact with the boat. Care should be taken to prevent the weighted end towing too deeply in the water with too long a line, or too high out of the water with too short a line and too high a speed. The correct attitude is with the weights just at the average surface.

The staff is left in place during the tests ready for further recording at the end of testing that day, or for recording sea during testing if required. The staff is recovered by picking up the mooring buoy, hauling up the weighted end (and anchor if attached) and towing it back to its wait location in the boat basin.

This method may work well in sea states one and two but breakages may occur in sea three due to the hogging bending moment when the floats are on top of a large wave going into the sea, or due to being caught in a breaking sea.

If this occurs, a second method of handling may be preferable. In this, the staff is taken out, lashed on the deck of the chase boat in its three separate lengths. The staff is taken out to its recording location and the weighted end of the lower section lowered over the side and held at its upper end. If necessary the test boat or other boat may help to form a lee. The second or center section of the staff is fitted in place with both sections held vertically, using the cone fitting and locking pin. The locking pin is a plain pin which is lashed in position for ease of handling and security.

C 11.4 Photography

The usefulness of the photography depends on a) the skill of the photographer to keep the water surface on the staff in view as steadily as possible, with correct focus, no glare from the sun and minimum spray on the lens; b) the skill of the boat operator in keeping the chase boat on the correct station (steady) relative to the direction of sway or lean of the staff (see below), sun and waves, and steady heading convenient to the photographer.

Photography should be close enough so that the upper end of the staff remains in view at the top of the frame while the water surface is in view at all times in the lower two thirds of the frame. This should be done by having the boat remain not more than 30 feet or one boat length in all sea states, and not by zooming the lens to the telephoto end of its adjustment.

The staff is expected to lean with the effect of current, and sway with the passing of each wave.

The photographs should be taken, and the boat held stationary, so that the true angle of lean of the staff in the current is recorded if it is more than  $10^\circ$ . The sway angle may be in the same direction as the waves and this will normally be recorded during photography by taking film at right angles to the direction of sway, or along the wave crests.

The photographs should be taken so that no intervening sea obscures the level of water at the staff. If the sway of the staff dictates that the film is taken looking other than along the line of crests (away from the sun), then the camera must be held high enough, or the boat moved close enough to avoid the interposition problem.

The appropriate caution must be exercised by the helmsman while holding station to avoid entangling the mooring float and line.

All photographs will be identified by taking two second shots of the run board of the day before and after each sequence of film of the staff. Films will be developed and viewed on the viewer at Oceanside before sending to Kensington in order to pick up any faults in the film. This should be done as quickly as possible to permit correction of faults before the next filmed data is taken.

The movie camera speed can be calibrated by photographing a stop watch.

## APPENDIX D

### DEFINITIONS

#### D 1 PURPOSE

The purpose of this Appendix is to provide a list of terms, and definitions thereof, most frequently used or encountered in the conduct of development and test operations.

#### D 2 TERMS AND DEFINITIONS

##### D 2.1 Assembly

A group of two or more physically connected or related parts which is capable of disassembly (carburetor, powerpack, IF circuit, amplifier). (Ref. 8.5)

##### D 2.2 Check Test

A retest performed on a service test model of selected items to determine whether major deficiencies found in the service test have been corrected, these deficiencies being of such a nature that the item was found unsuitable for type classification. (Ref. 8.1)

##### D 2.3 Comparison Test

A comparison test is a test of random samples of production line items, conducted as a quality assurance to detect any design, manufacturing or inspection deficiencies that may reduce the effective operation of the items by the using agency. (Ref. 8.1)

##### D 2.4 Component

A group of connected assemblies and parts which is capable of operation independently but may be externally controlled or derive its power from another source (computer, engine, transmission, electrical generator). (Ref. 8.5)

##### D 2.5 Confirmatory Test

A test or investigation of a production item or system after type classification as standard or limited production using early production models, to insure that required modifications not previously tested are acceptable (type I) or to preclude time consuming retrofit programs on selected items by expedited test in the field, using TOE-type units for the conduct of the test (type II). Where a confirmatory test has been determined necessary, the Chief, Amphibian Vehicle Division, Quantico, Virginia will indicate the appropriate test objective. (Ref. 8.1)

#### D 2.6 End Item

A combination of components, assemblies, and/or parts which is ready for its intended use. (Ref.8.5)

#### D 2.7 Engineering Test

A test conducted by or under supervision of a separate test agency; not a part of developing installation or technical agent concerned, using an engineering approach, where the objective of the test is to determine the technical performance and safety characteristics of an item or system and its associated tools and test equipment as prescribed in the Specific Operational Requirement (SOR), the technical characteristics and as indicated by the particular design. This determination includes the measurement of the inherent power, motion, structural, electrical, or other physical and chemical properties and may utilize data previously generated in Engineer Design Test. The test is characterized by controlled conditions and the elimination of human errors in judgment, so far as possible, through the utilization of environmental chambers, physical measurement techniques; controlled laboratory, shop, and field trials; statistical methodology; and the use of personnel trained in the engineering or scientific fields. The engineering test provides data for use in further development and for determination as to the technical and maintenance suitability of the item or system for service test. (Ref. 8.1)

#### D 2.8 Integrated Engineering Service Test

An integrated test is the conduct of engineering and service tests integrated to an optimum degree, normally at one location. An integrated test may be characterized by complete integration throughout the test, or a test in which only some phases are integrated. In some cases, an integrated test may be expanded to include engineer design test. (Ref. 8.1)

#### D 2.9 Limited Production Type Materiel

An item under development, commercially available or available from other Government agencies for which an urgent operational requirement exists and for which no other existing item is adequate; which appears to fulfill an approved qualitative materiel requirement or other U. S. Marine Corps approved requirements, and to be promising enough operationally to warrant initiating procurement and/or production for troop issue prior to completion of development and/or test or adoption as a standard item. (Ref. 8.4)

#### D 2.10 Limited Standard Type Materiel

Items which are not acceptable for United States Marine Corps operational requirements and will not, therefore, be counted as assets against operational requirements. Items in this category will be limited to:

- (a) Those which are not acceptable to meet operational requirements, but which are useful in training.
- (b) Those which are not acceptable to meet operational requirements of the U. S. Marine Corps but which are being retained to meet peculiar requirements other than those in (a) above. Items will be classified under the provisions of this paragraph only at the request of the Assistant Chief of Staff for Logistics, Headquarters, United States Marine Corps.

D 2.11 Major Assembly

A self-contained unit of individual identity. A completed assembly of component parts ready for operation, but utilized as a portion of, and intended for, further installation in an end item or major item. (Ref. 8.5)

D 2.12 Major Item

Same as end item.

D 2.13 Military Characteristics

Those characteristics of equipment upon which depend its ability to perform desired military functions. Military characteristics include physical and operational characteristics but not technical characteristics. (Ref. 8.5)

D 2.14 Military Potential Test

A test of a system, item, or component for which no definitive characteristics have been established or conducted for the purpose of determining whether the materiel or equipment has military potential. Normally a limited test conducted under field conditions. This test does not negate the requirement for engineering and service tests prior to type classification. (Ref. 8.1)

D 2.15 On-Equipment Materiel (OEM)

Items of supply which, although not part of the equipment proper, are issued with and accompany equipment. They are required for equipment first echelon maintenance, operation, armament, fire protection, communications, etc., and to complete the major end item for issue to users. Examples: Gun mounts, guns, radios, flashlights, fire extinguishers, sighting and fire control equipment, specified equipment (spare) parts and tools for maintenance of the equipment. (Ref. 8.5)

D 2.16 Part

An item which cannot be disassembled or is of such design that disassembly is impractical (bracket, gear, resistor, toggle switch, potted circuit). (Ref. 8.5)



#### D 2.17 Product Improvement Test

A test conducted on standard items which have been modified to correct deficiencies discovered during use, to simplify equipment operation or design, to increase reliability and durability, or to promote personnel safety. This test is for the purpose of verifying that essential military characteristics have not been adversely affected and to establish the durability, operational capability, and maintainability of the modified item. (Ref. 8.1)

#### D 2.18 Specific Operational Requirement (SOR)

A Specific Operational Requirement will state a need for a capability, will outline a system or major component for achieving it and will state the reasons for the requirement. An SOR will constitute a directive to an "appropriate Marine Corps agency" for the preparation of a Technical Development Plan to accomplish the objective stated. (Ref. 8.8)

#### D 2.19 Repair Part

Any part, assembly, or component which is required for installation in the maintenance of an end item, assembly or component. (Ref. 8.5)

#### D 2.20 Service Test

A test conducted under simulated or actual field conditions where the objective is to determine to what degree the item or system and its associated tools and test equipment perform the mission as described in the SOR, and the suitability of the item or system and its maintenance package for use by the United States Marine Corps. The test is characterized by qualitative observations and judgement of selected military personnel having a background of field experience with the type equipment undergoing test, with instrumentation limited to those measurements of characteristics of major operational significance. The test is conducted using Marines representative of those who will operate and maintain the equipment in the field. The service test provides the basis for recommendations on type classification. (Ref. 8.1)

#### D 2.21 Standard Type Materiel

The standard types designate the items that have been adopted as suitable for United States Marine Corps use (or other agencies when the United States Marine Corps is the supply agency); which are acceptable as assets to meet operational requirements; are authorized for inclusion in equipment authorization documents; and are described in published adopted item lists. There may be more than one standard type or more than one item of any specific standard type to fulfill the same requirement. Standard types are subdivided as follows:

- (a) Standard A. The most advanced and satisfactory items currently available to fill operational requirements.

- (b) Standard B. Items which have limited acceptability to fill operational requirements. These items are normally used and issued as substitutes for standard A items.
- (c) Standard C. Items which have only marginal acceptability for operating requirements, and are being forced out of the system as stocks of more acceptable items become adequate to meet requirements. (Ref. 8.4)

#### D 2.22 Technical Characteristics

Those characteristics of equipment which pertain primarily to the engineering principles involved in producing equipment possessing desired military characteristics, e.g., for electronic equipment, technical characteristics include such items as circuitry and types and arrangements of components. (Ref. 8.5)

#### D 2.23 Troop Test

A "troop test" is a test conducted by field units for the purpose of testing operational or organizational concepts, doctrines, tactics and techniques, or to gain further information on material integrated with the foregoing procedures. Whenever possible all significant items of new material will be thoroughly troop tested prior to adoption in a wide variety of environmental conditions throughout the FMF's.

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